

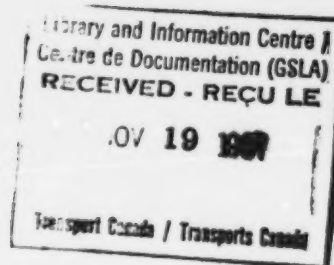
PARTS OF THE ORIGINAL DOCUMENT
ARE OF POOR REPRODUCTIVE QUALITY

CERTAINES PARTIES DU DOCUMENT ORIGINAL
SONT DE PIÈTRE QUALITÉ DE REPRODUCTION

CAL
DTC 800
87
M41
c.2



CANADIAN ASTRONAUTICS LIMITED



TP8394E

• MLS ANTENNA TEST FACILITY •
DESIGN, FABRICATION, AND
PRELIMINARY TEST OF AN MLS
FIRST ARTICLE ANTENNA TEST FACILITY

Prepared For: Transportation Development Centre
Guy-Favreau Complex
200 Dorchester Blvd. West
Suite 601, West Tower
Montreal, Quebec H2Z 1X4

Prepared By: Canadian Astronautics Limited
1050 Morrison Drive
Ottawa, Ontario

Authors: D.M. Ball, D. Frischknecht, S. Radhakant
Date: March 1987
SSC Contract #: T8200-5-5552
CAL Report #: 381-CAL-RT-10549

Note: The contents of this report reflect the view of the contractor and not necessarily the official views or policies of the Transportation Development Centre.

Un sommaire en français de ce rapport est inclus avant la Table des matières.

PROJECT TEAM

The project team for Canadian Astronautics consisted of:

Mr. D. Ball
Mr. P. Borkowski
Ms. D. Frischknecht
Mr. S. Radhakant
Mr. J. Whelpton

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the advice and assistance provided by:

- Mr. J. Hastie, Transport Canada
- Mr. G. Einarsson, Transport Canada

REPORT DOCUMENTATION FORM

1 Transport Canada Report No TP8394E		2 TDC Project No 6549/6551		3 Recipient's Catalogue No	
4 Title and Subtitle MLS Antenna Test Facility Design, Fabrication and Preliminary Test of an MLS First Article Antenna Test Facility				5 Report Date March 1987	
				6 Performing Organization Report No 381-CAL-RT-10549	
7 Author(s) D.M. Ball, D. Frischknecht, S. Radhakant				8 Transport Canada File No D1455-153-5	
9 Performing Organization Name and Address Canadian Astronautics Ltd. 1050 Morrison Drive Ottawa, Ontario K2H 8K7				10 DSS File No T8200-5-5552	
				11 DSS or Transport Canada Contract No OSD85-00252	
12 Sponsoring Agency Name and Address Transportation Development Centre (TDC) 200 Dorchester Blvd. West Suite 601, West Tower Montreal, P.Q. H2Z 1X4				13 Type of Report and Period Covered Final - Jan. 86-Mar. 87	
				14 Sponsoring Agency Code	
15 Supplementary Notes				16 TDC Project Officer M. Avni	
17 Abstract This report describes a project undertaken to develop a Microwave Landing System (MLS) antenna test facility. MLS, which is to become the standard aircraft landing instrument by 1995, will provide dramatically increased coverage, making airborne testing difficult and expensive. A previous Transport Canada study recommended a nearfield ground test facility be used to test the MLS to reduce the extent and cost of airborne tests. The radiated sidelobe performance of an MLS must be examined in detail in order to determine the effects of multipath in an airport environment. The MLS Antenna Test Facility has been developed to permit accurate and reliable measurement of antenna sidelobe performance, unmodified by the physical effects of normal airport geography (i.e. ground, buildings, etc). The test facility can also be used to evaluate and compare guidance angle accuracy and signal power levels of different MLS vendor products at a "clean" site, which assures more comprehensive test data. Once the test data is available, the performance at airports with vastly different geographical layouts can be predicted and special installation requirements identified. The system has been installed at David Florida Labs in Ottawa, Ontario, and is currently undergoing evaluation tests.					
18 Key Words Microwave Landing System Air Traffic Control Navigation Testing			19 Distribution Statement Limited number of copies available from Transport Development Centre (TDC)		
20 Security Classification (of this report) UNCLASSIFIED		21 Security Classification (of this page) UNCLASSIFIED		22 No. of Pages 37	
				23 Price NIL	



FORMULE DOCUMENTAIRE DU RAPPORT

1 N° du rapport Transports Canada TP8394E	2 N° de l'étude — CDT 6549/6551	3 N° de catalogue du destinataire
4 Titre et sous-titre MLS Antenna Test Facility: Design, Fabrication and Preliminary Test of an MLS First Article Antenna Test Facility	5 Date du rapport mars 1987	6 N° du rapport de l'organisme exécutant 381-CAL-RT-10549
7 Auteur(s) D. M. Ball, D. Frischknecht, S. Radhakant	8 N° de dossier Transports Canada D1455-153-5	
9 Nom et adresse de l'organisme exécutant Canadian Astronautics Ltd. 1050 Morrison Drive Ottawa, Ontario K2H 8K7	10 N° de dossier — ASC T8200-5-5552	11 N° de contrat — ASC ou Transports Canada OSD85-00252
12 Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) 200 ouest boul. Dorchester Suite 601, Tour ouest Montréal, Québec H2Z 1X4	13 Genre de rapport et période visée Final - jan 86-mars 87	14 Code de l'organisme parrain
15 Remarques additionnelles	16 Agent de projet — CDT M. Avni	
17 Résumé Ce rapport décrit la mise au point d'une installation d'essai au sol des antennes composant les systèmes d'atterrissage hyperfréquences (MLS). En raison de la couverture beaucoup plus étendue du MLS, qui deviendra l'instrument standard pour l'atterrissage d'avion en 1995, les essais en vols s'annoncent difficiles et coûteux. Une récente étude effectuée par Transports Canada a recommandé l'utilisation d'une installation d'essai au sol, en champ proche, dans le but de réduire le nombre, l'ampleur et le coût des essais en vol. Le comportement des lobes latéraux du MLS devra être étudié en détail en vue de déterminer les effets des trajets multiples dans un environnement aéroportuaire. L'installation d'essai de l'antenne MLS a été mise au point pour permettre la mesure précise et fiable du comportement des lobes latéraux, à l'abri des effets perturbateurs d'un environnement aéroportuaire normal (c'est-à-dire le sol, les bâtiments, etc.). L'installation d'essai peut également servir à évaluer et à comparer la précision de l'angle de guidage et le niveau de puissance du signal émis par différents produits MLS de commerce, dans des conditions parfaitement contrôlées qui permettent d'obtenir des données d'essai plus complètes. Après l'obtention des données d'essai, il sera possible de prévoir la performance du système dans des aéroports de configuration très différente et d'identifier les besoins particuliers d'installation. Le système, qui a été installé au laboratoire David Florida à Ottawa, Ontario, est présentement en cours d'évaluation.		
18 Mots-clés Système d'atterrissage hyperfréquence Contrôle de la circulation aérienne Navigation Essai	19 Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires	
20 Classification de sécurité (de ce rapport) non classifié	21 Classification de sécurité (de cette page) non classifiée	22 Nombre de pages 37
		23 Prix Nil

SUMMARY

The MLS Antenna Test Facility Report describes the objectives of the project, provides a description of the equipment supplied, and summarizes the results of preliminary tests on the system.

Introduction

The Microwave Landing System (MLS) has the capability to cover a huge volume of air space with very accurate glide path and azimuth guidance signals, making MLS testing more demanding than testing of Instrument Landing Systems (ILS). Spatially variant signal measurement at an airport site is particularly difficult due to the effects of multipath, which causes irregularities in the shape of the beam as it sweeps past the receiver, degrading both received signal strength and guidance angle accuracy.

A Transport Canada study recommended a nearfield ground test facility be used to test the MLS to reduce the extent and cost of airborne tests. Since measurements are taken in the antenna nearfield, a multipath prediction technique is necessary to predict far-field multipath effects. On the basis of this prediction, flight testing may be constrained to the published approach path and those areas where multipath is predicted to be significant, thereby reducing the flight test requirements, minimizing both airport downtime and cost of the tests.

The radiated sidelobe performance of an MLS must be examined in detail in order to determine the effects of multipath. The MLS Antenna Test Facility has been developed to permit accurate and reliable measurement of antenna sidelobe performance, unmodified by the physical effects of normal airport geography (ie., ground, buildings, etc.). The test facility can also be used to evaluate and compare performance of different MLS vendor products at a "clean" site, which assures more comprehensive test data. Once the test data is available, the performance at airports with vastly different geographical layouts can be predicted and special installation requirements identified.

Objectives of Development

The MLS Antenna Test Facility to be developed must perform the following measurements on MLS Azimuth, Elevation and Back Azimuth systems:

- Accurately measures the angle accuracy throughout the coverage volume
- Calculates dynamic sidelobe level
- Measures radiated power for all signals, (ie., level of frame preamble, right and left Out of Coverage Indicator, TO/FRO or scanning beam signal and right and left clearance pulses).
- Measures effect of polarization on guidance accuracy

The receiver output video signal is to be digitized, then analyzed on a 68000 based microcomputer, using a software program which calculates radiated power, beam pointing angle and dynamic sidelobe level. The calculated sidelobe levels can then be coupled with an airport reflection model to predict flight zones where multipath might be expected to be a problem or to predict the effects of adding new structures in the airport vicinity. The Analyzer is also required to remotely control the MLS mounting turntable to automate the testing process and reduce the test time.

System Description

The following equipment is included with the test facility:

- Receiving Antenna
- Receiver Subsystem
- Digitizer/Processor unit, including printer, plotter, CRT/keyboard
- Guidance Angle/Sidelobe Simulator
- Turntable Remote Controller
- Digital Tape Recorder

Additional equipment supplied by Transport Canada includes a turntable for mounting the MLS and a turntable driver. The turntable and receiving antenna are mounted sufficiently high (20 m and 60 m respectively) to reduce site multipath to a negligible amount.

The First Article MLS Test Facility (FAMAT) system is a 68000 based computer system that performs first article tests on MLS antennas. The tests are conducted by positioning a turntable on which the MLS antenna is mounted, and which simulates different aircraft approach angles. This beam, transmitted and swept by the antenna, is received by a commercial MLS receiver. The signal from the receiver is fed to a digitizer, which digitizes the data every two microseconds and feeds the data to the computer. The software calculates the MLS transmitted angle, compares this with the angle as read from the turn-table, and then stores the error angle for later output. The signal is also analyzed to find dynamic sidelobe levels and all signal levels. This information is sent to the console, a printer and a plotter, thus producing documented performance characteristics of the antenna under test.

The FAMAT system consists of a number of inputs, each being processed in some different fashion, giving rise to a number of computed outputs. The system is divided into a number of modules, each of which is as independent of the others as possible, and also performs unique tasks. An attempt has been made to keep modules fully cohesive, that is, all tasks performed by a module are intimately connected.

The software is required to perform four major tasks, i.e. OPINT, FAMAT, TURN and OUTPUT. OPINT allows the operator to enter parameters and to start program execution. FAMAT controls the digitization and storage of data and starts the TURN task, which directs the turntable to change position. The processed data from FAMAT is sent to the OUTPUT task, which displays, prints, plots or stores the results.

Preliminary Test Results

Preliminary tests of the system were divided into three sets, i.e. factory acceptance tests, field demonstration tests, and DFL tests.

Factory acceptance included test of the measurement accuracy of guidance angle, power level, and sidelobe levels, as well as performance testing on the operator interface, and the printer, plotter, and tape recorder.

A field demonstration was provided at David Florida Labs (DFL) using a Transport Canada supplied MLS. The capability to control the turntable, to read the position encoder, and to measure radiated signals was demonstrated. Plots of guidance angle error and dynamic sidelobe level were produced as well as printed output forms.

DFL tests included antenna gain testing, multipath measurements, encoder testing and tower/building motion tests.

Conclusions and Recommendations

Preliminary tests have demonstrated that the system can be successfully used to measure all radiated signal levels, guidance angle error and dynamic sidelobe levels of an MLS.

It is recommended that more exhaustive field tests be performed on the FAMAT test system using a typical MLS transmitter, thereby confirming that the FAMAT system works well under all conditions. For example, tests under conditions of heavy rain and high winds should be conducted. The MLS Elevation unit should also be installed and the effect, if any, of testing an antenna "tipped" on its side be determined.

It is also recommended that the test system be moved to an airport and used, with a probe antenna mounted on a short mast, to determine whether airport ground multipath will affect measurement accuracy. Assuming this test is successful, it is recommended that full development of an airport Commissioning Test Facility be undertaken.

The MLS test facility has demonstrated that ground based testing of an MLS is practical. It is anticipated that the ground based testing approach will be of greatest benefit both in reducing the costs of MLS testing in the future and in predicting the performance of various types of MLS for the vastly different airport geographies found across Canada.

SOMMAIRE

Le présent rapport sur l'installation d'essai d'une antenne MLS décrit les objectifs du projet, donne une description du matériel fourni et résume les résultats des essais préliminaires du système.

Introduction

Le système d'atterrissage hyperfréquence MLS émet des signaux très précis d'alignement de descente et de guidage en azimuth dans un très large volume. Cette caractéristique fait que le système MLS est beaucoup plus exigeant sur le plan des essais que les systèmes d'atterrissage aux instruments (ILS). La mesure de signaux variables dans l'espace est particulièrement difficile sur un site aéroportuaire à cause des trajets multiples qui modifient la forme de faisceau lorsqu'il passe devant le récepteur, réduisant aussi bien la force du signal reçu que la précision de l'angle de guidage.

Une étude effectuée par Transport Canada recommandait l'utilisation d'une installation d'essai au sol du MLS, en champ proche, afin de réduire l'ampleur et le coût des essais en vol. Les mesures étant prises à proximité de l'antenne, il est nécessaire d'adopter une technique de prévision des trajets multiples qui permette d'en prévoir les effets en champ lointain. Connaissant ces effets, on peut restreindre les essais en vol à la trajectoire d'approche standard à l'aéroport concerné et aux zones où justement on prévoit une influence marquée des trajets multiples. Résultat: moins d'essais en vol à faire, durée de fermeture des aéroports réduite et coûts moindres.

Le comportement des lobes latéraux d'un MLS doit être étudié en détail afin de déterminer les effets des trajets multiples. L'installation d'essai de l'antenne MLS a été mise au point pour permettre la mesure précise et fiable du comportement des lobes latéraux, à l'abri des effets perturbateurs d'un environnement aéroportuaire normal (sol, bâtiments, etc.).

L'installation d'essai peut également servir à évaluer et à comparer la performance de différents produits MLS du commerce dans des conditions parfaitement contrôlées permettant d'obtenir des données d'essai, il sera possible de prévoir la performance du système dans des aéroports de configuration très différente et d'identifier les besoins propres à chaque site.

Objectifs de développement

L'installation d'essai à mettre au point doit pouvoir renseigner sur les caractéristiques suivantes des composantes azimuth, site et azimuth arrière des systèmes MLS:

- Valeur précise de l'angle de décalage par rapport à l'axe de piste.
- Variation d'amplitude des lobes latéraux dynamiques.
- Puissance rayonnée pour tous les signaux (c'est-à-dire préambule de cadre, indicateur de non couverture à gauche et à droite, signal de balayage latéral en site et impulsions de marge à gauche et à droite).
- Effet de la polarisation sur la précision de guidage.

Le signal vidéo de sortie du récepteur doit être numérisé et analysé sur un micro-ordinateur de type 68000 assorti d'un logiciel qui calcule la puissance rayonnée, l'angle de pointage du faisceau et l'amplitude instantanée du lobe latéral dynamique. Les amplitudes calculées du lobe latéral peuvent ensuite être couplées à un modèle de réflexion de l'aéroport étudié pour prévoir soit les zones de vol où les trajets multiples sont susceptibles de poser des difficultés, soit les effets que pourrait entraîner l'érection de nouvelles structures à proximité d'un aéroport. L'installation d'essai doit également comprendre un analyseur apte à commander à distance le plateau oscillant du MLS, de manière à automatiser la méthode d'essai et à réduire les temps d'exécution.

Description du système

L'installation d'essai comprend le matériel suivant:

- Antenne de réception.
- Sous-système de réception.
- Bloc convertisseur analogique/numérique/processeur comprenant une imprimante, un traceur et un écran d'affichage/clavier.
- Simulateur d'angle de guidage et de lobe latéral.
- Commande à distance du plateau oscillant.
- Enregistreur à bande numérique.

En plus, Transports Canada fournit un plateau oscillant pour l'installation du MLS et un dispositif d'entraînement du plateau, lesquels sont installés à une hauteur suffisante (respectivement à 20 m et à 60 m) afin de réduire au minimum les trajets multiples sur le site.

L'installation d'essai de premier article de série MLS (FAMAT) est un ordinateur de type 68000. Les essais consistent à positionner un plateau oscillant sur lequel est montée l'antenne MLS de manière à simuler différents angles d'approche d'un aéronef. Le faisceau émis par l'antenne est capté par un récepteur MLS commercial. Le signal capté par le récepteur est soumis à un convertisseur analogique/numérique qui numérise les données à toutes les deux microsecondes et fournit les données à l'ordinateur. Le logiciel calcule l'angle d'approche, compare ce dernier à l'angle qui apparaît sur le plateau oscillant et mémorise l'écart entre les deux pour usage ultérieur. Le signal est également analysé pour déterminer les valeurs dynamiques du lobe latéral et la valeur de tous les signaux. Cette information est envoyée au pupitre de commande, à l'imprimante et au traceur pour documenter les caractéristiques de performance de l'antenne à l'essai.

Le système FAMAT repose sur un certain nombre d'entrées, dont chacune fait l'objet d'un traitement différent, et qui permettent d'obtenir un certain nombre de résultats. Le système se divise en modules, aussi indépendants que possible les uns des autres et qui remplissent des tâches uniques. On a tenté de rendre ces modules entièrement cohérents, c'est-à-dire de faire en sorte que toutes les fonctions d'un module soient intimement reliées.

Le logiciel doit remplir les quatre fonctions principales suivantes: OPINT, FAMAT, TURN et OUTPUT. La fonction OPINT permet à l'opérateur d'introduire les paramètres et d'amorcer l'exécution du programme. La fonction FAMAT commande la numérisation et le stockage des données et amorce la fonction TURN qui commande les changements de position du plateau oscillant. Les données traitées de FAMAT sont acheminées à la fonction OUTPUT qui affiche, imprime, trace ou mémorise les résultats.

Résultats des essais préliminaires

Les essais préliminaires du système ont été divisés en trois groupes: essais d'acceptation du matériel, essais de démonstration sur le terrain et essais au Laboratoire David Florida.

Les essais d'acceptation ont consisté à mesurer la précision de l'angle de guidage, le niveau de puissance rayonné et les niveaux du lobe latéral ainsi qu' à vérifier les performance de l'interface homme-machine, de l'imprimante, du traceur et de l'enregistreur à bande numérique.

La démonstration sur le terrain a été effectuée aux Laboratoires David Florida (DFL) à l'aide du MLS fourni par Transports Canada. Les essais ont démontré la possibilité de commander le plateau oscillant, de lire le codeur d'angle et de mesurer les signaux rayonnés. Les erreurs d'angle de guidage et les variations d'amplitude du lobe latéral ont été mises en graphique et compilées sous forme de listings numériques.

Les essais effectués au DFL ont porté sur le gain d'antenne, la mesure des trajets multiples, la fiabilité du codeur d'angle et la détermination des mouvements des tours/bâtiments.

Conclusions et recommandations

Les essais préliminaires ont permis de démontrer que le système peut être utilisé avec succès pour mesurer le niveau de tous les signaux rayonnés, l'erreur de l'angle de guidage et les niveaux dynamiques du lobe latéral d'un MLS.

Il est recommandé que ce système soit utilisé pour faire l'essai détaillé d'un MLS, en vue de confirmer son bon fonctionnement dans toutes les conditions. Ainsi, des essais devraient être effectués dans des conditions de fortes pluies et de grands vents. Il faudrait également tester l'antenne de balayage en site du MLS le plateau oscillant en la plaçant debout, sur le côté, et déterminer si cette position a un effet secondaire quelconque.

On recommande également que le système d'essai soit installé dans un aéroport, avec une antenne sonde montée sur un mât court, dans le but de déterminer si les trajets multiples au sol dans un aéroport influenceront sur la précision des mesures. À la condition que cet essai soit concluant, le développement intégral d'une installation d'essai de mise en service d'un aéroport est recommandé.

L'installation d'essai au sol d'un MLS s'est Révélée satisfaisante. On peut donc espérer que cette méthode d'essai au sol permettra de réduire les coûts d'essais d'un MLS dans l'avenir et aussi de prévoir la performance de divers types de MLS dans la grande variété de sites aéroportuaires que l'on trouve à travers le Canada.

Table of Contents

	Page
1.0 INTRODUCTION	1-1
2.0 OBJECTIVES OF PROJECT	2-1
2.1 SYSTEM DESIGN	2-1
2.1.1 MLS ANTENNA TEST FACILITY	2-1
2.1.2 GUIDANCE ANGLE SIMULATOR	2-4
2.1.3 ENVIRONMENTAL TEST FACILITY	2-5
2.1.4 COMMISSIONING MLS TEST FACILITY	2-7
3.0 DESCRIPTION OF EQUIPMENT	3-1
3.1 COMMISSIONING TEST FACILITY	3-1
3.2 ENVIRONMENTAL TEST FACILITY	3-1
3.3 MLS ANTENNA TEST FACILITY	3-2
3.3.1 TRANSPORT CANADA PROVIDED FACILITIES	3-2
3.3.2 CAL-SUPPLIED HARDWARE DESCRIPTION	3-4
3.3.3 SOFTWARE DESCRIPTION	3-6
3.3.3.1 Data Flow Description	3-6
3.3.3.2 Data Structure	3-9
3.3.3.3 Synchronization Mechanism	3-14
3.3.3.4 Tasks	3-15
3.3.3.5 Command Files	3-26
4.0 PRELIMINARY TEST RESULTS	4-1
4.1 FACTORY ACCEPTANCE TESTS	4-1
4.2 FIELD DEMONSTRATION	4-2
4.3 DFL TESTS	4-6
5.0 CONCLUSIONS AND RECOMMENDATIONS	5-1
5.1 PRODUCT ENHANCEMENTS	5-2

LIST OF ILLUSTRATIONS

Figure 2.1	Block Diagram of a MLS Test Facility	2-2
2.2	Thermal Chamber Configuration	2-6
2.3	Scanning Beam Measurement Zone	2-8
2.4	CTF Block Diagram	2-9
3.1	MLS Antenna Test Facility	3-3
3.2	Data Flow Diagram for FAMAT	3-7
3.3	SADT Diagram for FAMAT	3-8
3.4	Structure Chart of FAMAT	3-17
4.1	Plot of Angle Error vs Encoder Angle	4-3
4.2	Plot of DSSL vs Encoder Angle	4-4
4.3	Printer Output Form	4-5
4.4	Photograph of Test System	4-6

LIST OF TABLES

Table 3.1	Structure of Record "Query"	3-10
3.2	Structure of Record "Param"	3-11
3.3	Data in "Menu"	3-12
3.4	Data in Record "Query"	3-13

1.0 INTRODUCTION

This document describes the project to design, build and conduct preliminary tests on a MLS Antenna Test Facility for the Transportation Development Centre (TDC) of Transport Canada.

The Microwave Landing System (MLS) is scheduled to become the prime aircraft landing system by 1998, replacing the present International Civil Aviation Organization (ICAO) standard VHF/UHF instrument landing system (ILS). MLS will provide greater accuracy and will extend flyable guidance over wider areas of coverage (up to 120° in azimuth and 30° in elevation) with much greater freedom from the effects of terrain irregularities and adverse weather conditions than with ILS. Because of its versatility, autoland accuracy, reduced installation costs and lower maintenance requirements, MLS will provide a greater capability than ILS to establish precision approaches when required, and will, therefore, provide important improvements in air transportation safety and efficiency. By allowing more direct landing approaches, under all weather conditions, aircraft fuel consumption could be reduced dramatically. Furthermore, the approach assistance provided by this system would facilitate helicopter or STOL aircraft landings during periods of low visibility.

The enhanced performance of the MLS will permit landings over difficult terrain and/or under low visibility conditions and, as a consequence, aircraft will become more and more dependent on these systems. This dependency will make it increasingly important that the accuracy is provided and maintained over the system lifetime.

In May 1985, Canadian Astronautics Limited (CAL) completed a study for TDC alternative techniques for testing MLS installations on the ground, with the objective of minimizing testing costs by reducing the requirement for expensive airborne testing. This study report^[1] concluded that an MLS Ground Test Facility is feasible, and that all MLS performance tests, with the possible exception of some multipath tests, can be performed utilizing ground equipment with its inherently lower operating costs.

^[1]Feasibility Study of an MLS Ground Certification and Measurement Feasibility, TDC, TP6501E, May 1985.

The major benefits of an MLS ground test facility are:

- The accuracy of the MLS will be thoroughly tested rapidly and easily on the ground with minimal disturbance to air traffic.
- Seasonal effects on MLS performance will be predicted in advance by testing at a controlled test facility.
- Multipath predictions, based on the test data, can minimize the time and effort required to assess the impact of airport structures on MLS accuracy in the air.

In addition to initial commissioning tests and periodic testing, the study also recommended that MLS First Article Antenna Production Run tests be conducted at a properly instrumented antenna test facility. Such a facility will provide both improved multipath prediction capability and will permit specialized environmental testing on the antenna; a task which is both difficult and expensive to perform at a busy airport.

This report includes the following sections:

- i) Objectives of Project
- ii) Description of Equipment
- iii) Test Results
- iv) Conclusions and Recommendations

2.0 OBJECTIVES OF PROJECT

The objective of this project was to design, build and conduct preliminary tests on an MLS Antenna Test Facility.

The project was split into two phases, where the objective of Phase 1 was to produce a system would be design description for Phase 2, during which the system designed in phase 1 would be built and tested. The major purpose of this split was to provide an opportunity to review the system design prior to proceeding with the build and test tasks.

2.1 SYSTEM DESIGN (PHASE 1)

A detailed design description was produced for an MLS antenna test facility, a guidance angle simulator, an environmental test facility and a commissioning test facility.

2.1.1 MLS ANTENNA TEST FACILITY

Figure 2.1 illustrates a block diagram of the proposed facility, which consists of the following major subsystems:

- Turntable with both Local and Remote Controller/Display
- High Resolution Position Encoder
- Receiving Antenna with polarization positioner and controller
- MLS Receiver
- MLS Processor
- Digital Recorder

The purpose of the MLS Antenna Test Facility is to:

- i) Provide a facility for comparative testing of various MLS suppliers' systems on a very low multipath site, for spatially variant parameters.
- ii) Provide antenna dynamic sidelobe test data in the plane of scan.

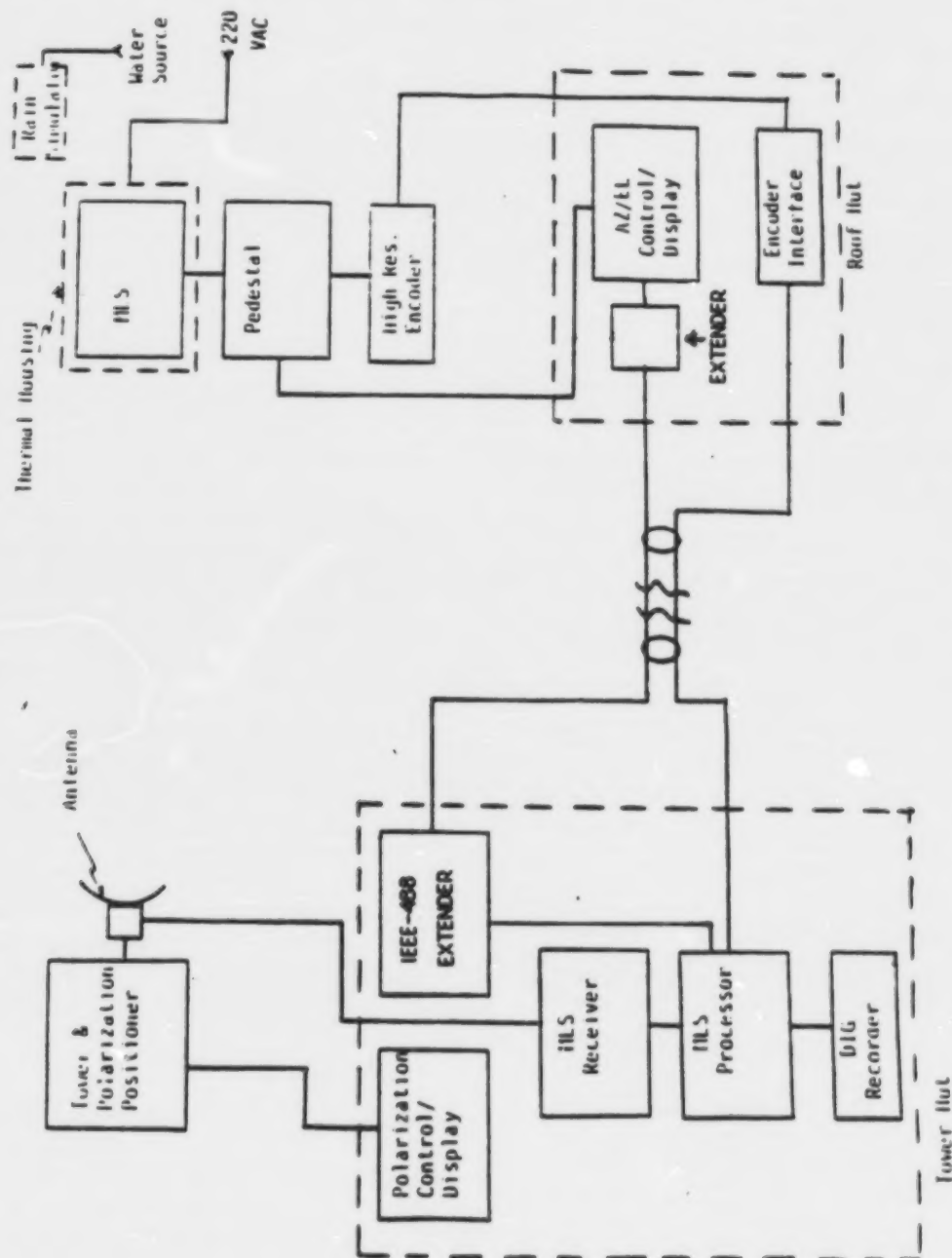


Figure 2.1 Block Diagram of MLS Test Facility

The system must be capable of measuring the following:

- Dynamic sidelobe level
- All spatially variant parameters such as power level and guidance accuracy
- Effect of polarization on guidance accuracy.

The system is required to provide the following information about the MLS Azimuth (AZ), Elevation (EL) or Back Azimuth (BAZ) signals.

1. The calculated angle of the scanning beam.
2. The received RF level of the frame preamble.
3. The level of the left and right OCI functions.
4. The level of the radiated sidelobes (dynamic).
5. The level of the scanning beam signal (both TO and FRO).
6. The level of the right and left clearance pulses.

The accuracy objective for the MLS Test System is ± 1.5 dB in absolute signal level and $\pm 0.004^\circ$ for the calculated angle of the scanning beam.

2.1.1.1 Antenna Test Range

A key constituent of the test facility is a low multipath antenna test range. The facility should ideally either have multipath at least 35dB down from the main lobe, or have the multipath carefully measured and controlled so that reflected multipath signals can be distinguished from sidelobes and therefore, subsequently ignored.

The facility recommended for these tests is the Communications Research Centre's David Florida Lab (DFL) roof mounted antenna test facility. This facility has the following features:

- a) Antenna test pedestal mounted on the edge of a building roof, 20 m from the ground.
- b) Receiving tower 396 m away at a height of 61 m from the ground.
- c) Movable diffraction fences available for ground multipath reduction, if required.

In order to reduce the importance of ground reflected multipath (which, in anything but a true free space facility, will always be present), the MLS shall always be tested with the beam scanning horizontally. This is appropriate because the principal and therefore, unless the ground surface is both asymmetrical and the reflection strong, no significant guidance error will result. (There will be an error in measured signal amplitude, but this error is usually small). Therefore, the EL system will have to be measured while "tipped" on its side.

The MLS is required to be mounted on the turntable, preferably with the antenna phase centre mounted over the centre of rotation. If the antenna phase centre is not mounted over the centre of rotation, the system shall be able to compute the correct bearing from the offset information supplied.

2.1.2 GUIDANCE ANGLE SIMULATOR

The primary purpose of the Guidance Angle Simulator shall be to perform sidelobe level accuracy tests on the MLS Antenna Test Facility.

In addition, the unit will be used to simulate the MLS scanning beam signal to determine the guidance angle and power measurement accuracy of the receiver/processor, and to ensure the analyzer accuracy does not degrade with time or temperature.

In order to simulate the scanning beam, an accurate ICAO defined video waveform is required to be simulated, including sidelobe levels. The method is based on using the computer in the MLS Signal Analyzer to generate a Taylor weighted beam pattern, which is then output to a high speed memory. The high speed memory can then be "read" in real-time through a D/A converter to create an analog video waveform, which is then up-converted to the required RF frequency (5.061 GHz) and is used to feed the MLS Signal Analyzer receiver input.

In addition, the function identification preamble for the AZ, EL and BAZ functions will be simulated so that the analyzer will recognize the signal as authentic. This preamble will also be generated by the computer.

2.1.3 ENVIRONMENTAL TEST FACILITY

The purpose of the Environmental Test Facility (ETF) is to test an MLS antenna under conditions of low temperature, high temperature and simulated rain.

The ETF shall be designed to be used with the MLS Antenna Test Facility and shall be capable of performing tests on a Hazeltine Model 2500 Azimuth MLS system. It is most desirable that the system also be able to measure performance of MLS Elevation systems, subject to the limitations imposed by the requirement for the antenna to be rotated 90°. It is also highly desirable that the system be capable of measuring MLS systems other than the Hazeltine 2500, subject to limitations imposed by the size of the ETF enclosure, the shape, size, power dissipation of the MLS system and the thermal resistance of the MLS system.

Temperature tests are to be designed to simulate an outdoor environment for the antenna portion of the MLS for temperatures of +50°C and -50°C. Rainfall rates of 0.6, 1.9 and 5.0 cm per hour are to be simulated with the antenna elevated to an angle of 2°.

A structure made of fiberglass material and styrofoam insulation is proposed to be constructed and placed around the MLS system. The structure needs to be sufficiently small that it will rotate on the pedestal with the MLS to avoid variations in performance due to the housing materials located in the radiating field. The front of the enclosure will be closed by a radome. A sketch showing the proposed ETF is shown in Figure 2.2. (It should be noted that this facility was not constructed).

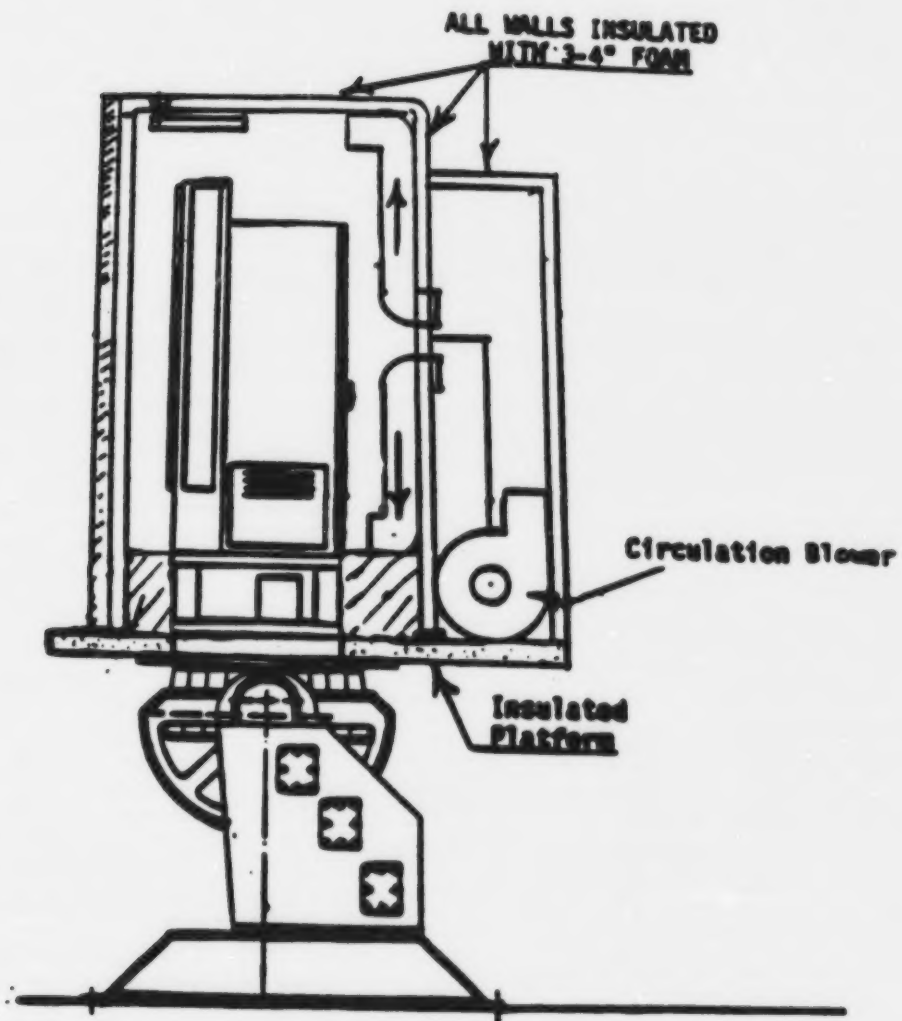


Figure 2.2 Thermal Chamber Configuration

2.1.4 COMMISSIONING MLS TEST FACILITY

A Commissioning Test Facility (CTF) is required to test and confirm that an MLS meets all the requirements of ICAO SARP (Annex 10) after installation. It was recommended that, as a result of the CAL study [1] undertaken in 1985, the CTF consist of a ground based system, supported by limited airborne testing to confirm that the multipath requirements are met.

The ground-based CTF measurement system is required to measure performance throughout the entire coverage volume, with the exception of performance degradation caused by multipath. The field probe portion of the test system is required to be located in the quasi-near field of the MLS antenna, nominally 30 to 35 metres in front of the antenna array. Figure 2.3 illustrates the scanning beam test measurement zone, at a distance of 32 meters from the MLS, for a wide scan ($\pm 60^\circ$) MLS system.

In order to measure the radiated signal parameters at the prescribed measurement points, a probe antenna will be required to be mounted on a transportable mast which can be elevated to a height of at least 13 metres. A receiver-processor unit is required to be connected to the probe antenna, to measure the ICAO specified parameters.

In order to perform the required measurements, the antenna must be movable up and down on the mast and the mast must be moveable as well, either trailer mounted, vehicular mounted, or sufficiently light to be moved by hand. Because the tests are to be performed at a relatively remote location on an airport, it is advisable the receiver-processor subsystem be contained either in a vehicle or transportable containers and that this subsystem include a source of power for the receiver-processor and the probe antenna. Figure 2.4 illustrates a system level block diagram of the system.

Because the location of the antenna with respect to the MLS Antenna phase centre is critical, a probe antenna tracking system is also needed. (This facility was also not constructed).

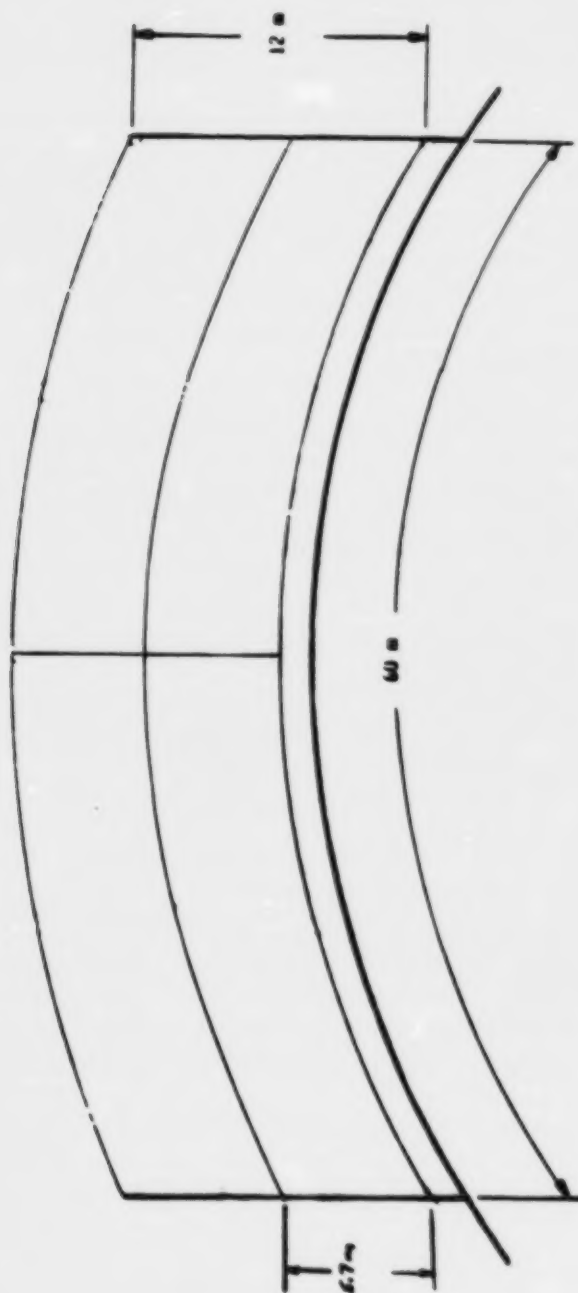


Figure 2.3 Scanning Beam Measurement Zone

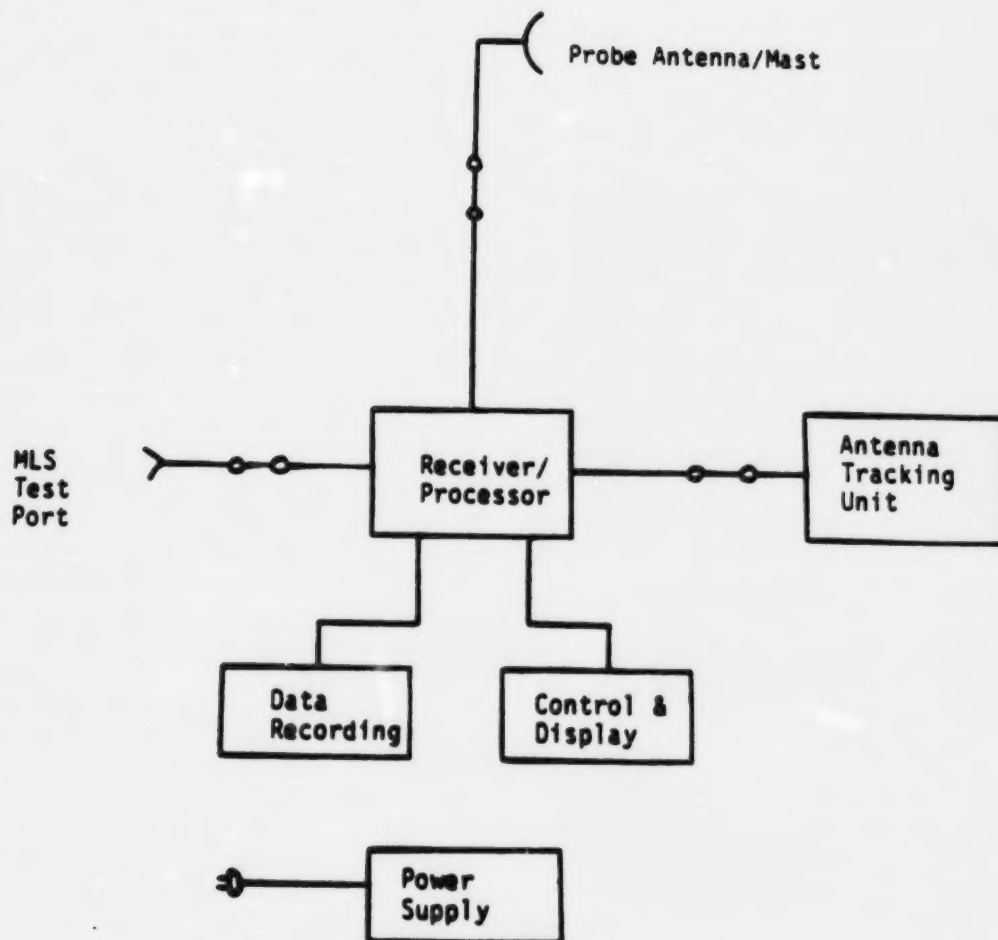


Figure 2.4 CTF Block Diagram



3.0 DESCRIPTION OF EQUIPMENT

Phase 1 of the study produced a functional equipment description for a:

- i) Commissioning Test Facility
- ii) Environmental Test Facility
- iii) MLS Antenna Test Facility

3.1 COMMISSIONING TEST FACILITY

It was decided that the MLS Antenna Test Facility should be constructed and tested prior to proceeding with the CTF. Therefore, no further work was done on the CTF.

3.2 ENVIRONMENTAL TEST FACILITY

The ETF was originally proposed to be part of the MLS Antenna Test Facility so that temperature and rain tests could be performed on the MLS system. However, upon closer examination it was determined that the cost of such a capability would be too high. The major reasons for the unexpected cost escalation were:

- i) Below 0°C, the Hazeltine MLS generates 3KW of extra heat
- ii) The unit would have to operate at +50°C under full sun load conditions, and with high winds on top of a 20 meter high building.
- iii) The unit would have to be operated in a non-research mode, (i.e.: by third party users with minimal skill level) therefore the design would have to be relatively mature.

Upon consultation with a firm specializing in manufacture of environmental cooling systems, it was determined that, unless the tests are conducted in a research-only mode, below 30°C, without sun load, and with the MLS auxiliary heating system disabled, the cost of the cooling unit would be unacceptably high.

Therefore, TDC elected to delete the requirement for an ETF.

3.3 MLS ANTENNA TEST FACILITY

Figure 3.1 illustrates the system block diagram of the MLS Test Facility. The system consists of two major subsystems, that is an antenna range facility, and a Receiver/Processor subsystem.

The antenna range facility was to be provided by Transport Canada and the Receiver/Processor Subsystem by Canadian Astronautics (CAL), with responsibility for system integration also being with CAL.

3.3.1 TRANSPORT CANADA PROVIDED FACILITIES

Listed below are all facilities and equipment that are provided by Transport Canada.

- a) Pedestal

Orbit Model AL4306-1 with BEI Model 5V682HB Absolute Encoder.
- b) Local Pedestal Controller and Display

SA Model 2012 Controller and Display, with GPIB Interface
- c) Interconnect cables from roof hut to tower hut for remote control, encoder link, and intercom
- d) Intercom system
- e) Polarization positioner (SA Model 5620A or similar) and antenna mount for tower
- f) Interconnect cable from tower platform to tower hut for polarization control
- g) Tower hut (~10 ft. x 10 ft., heated and A/C, with 115 V AC power)
- h) Installation and control of MLS
- i) GPIB Extenders (Qty 2)

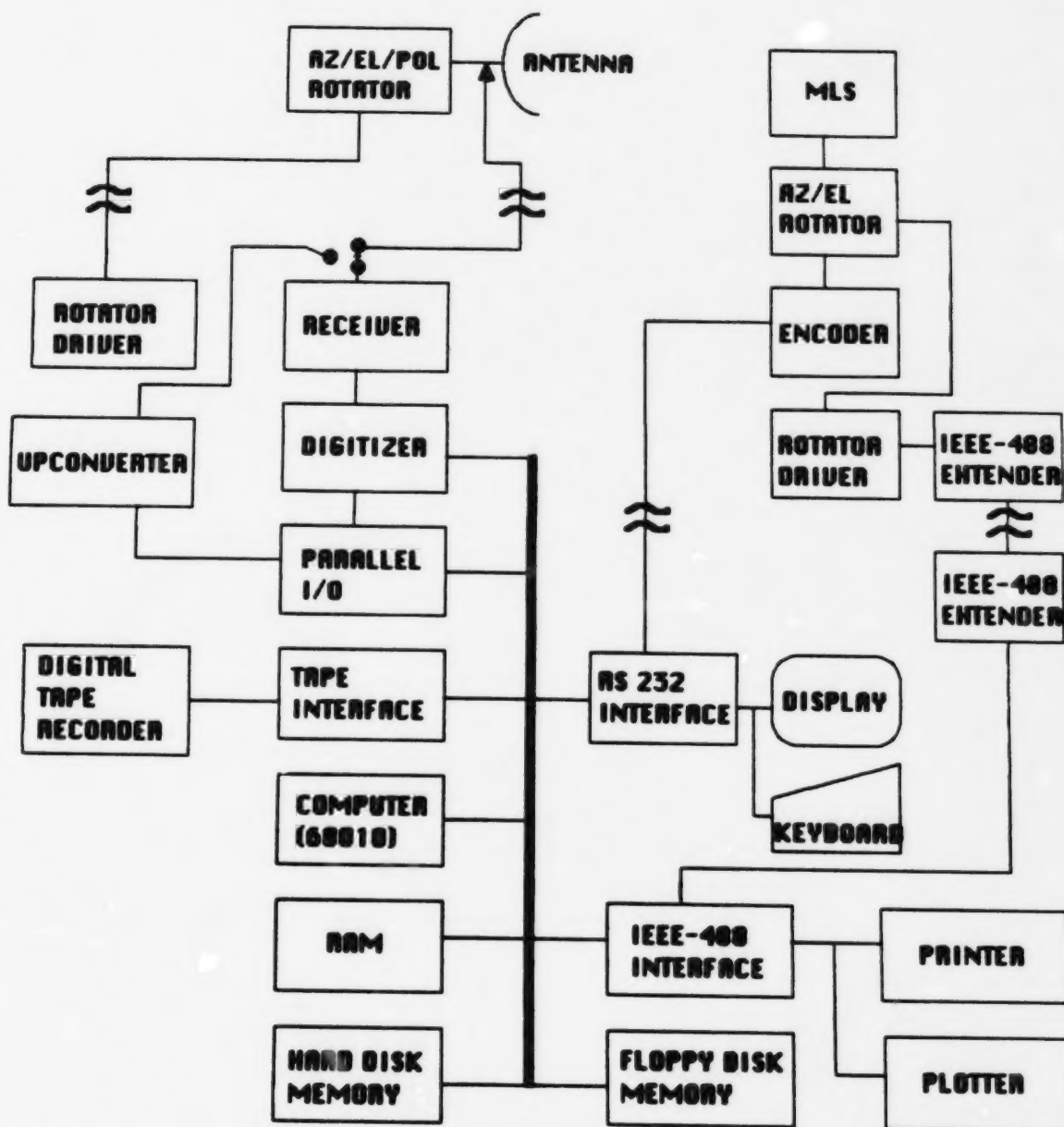


Figure 3.1 MLS Antenna Test Facility

3.3.2 CAL-Supplied Hardware Description

The CAL supplied hardware consists of the following equipment:

- Antenna (Andrews model PL644E)
- Receiver/Upconverter Unit
- MLS Process Unit
- Encoder Interface Unit
- Digital Tape Recorder (Kennedy model 9600)
- Computer (Motorola MVME 121DVSTS) including the following:
 - Parallel I/O Interface
 - Triple RS 232 Interface
 - GPIB Interface
 - RAM, 2 MBYTES
 - Winchester Disk
 - 5 $\frac{1}{4}$ " Floppy Disk
 - $\frac{5}{8}$ " Digital Tape Controller
 - DMA module
- Display/Keyboard (DEC VT 220)
- Printer (HP THINK JET)
- Plotter (HP 7470A)

a) Receiver/Upconverter Unit

The receiver portion of this unit is required to downconvert and amplitude detect the MLS 5 GHz RF signal, then supply a video signal to the MLS Processor Unit. It also must supply a DPSK demodulated signal to the Processor unit to provide the code identifying the radiated signal type. A 9 dB amplitude adjustment control is provided to increase the built-in Bendix MLS 20A receiver (supplied by Transport Canada) dynamic range.

The upconverter portion of this unit provides a signal at 5061 MHz (channel 600) for test purposes, which includes a modulator to permit video signals to be amplitude modulated on to the RF signal, and a PSK modulator to permit the carrier to be phase-shift keyed.

b) MLS Processor

The MLS Processor Unit consists of a 68000 based computer with its associated peripherals, a digitizer module, a GPIB interface module, a parallel I/O port, and a RS232 interface.

- i) The digitizer module consists of a 500,000 sample/sec digitizer which converts the MLS video signal to digital form. The data is then passed through a gain linearizer module and transferred to the computer memory via a DMA link. The DPSK identification code is used to start the digitizing operation when the code matches the operated requested function type.
- ii) The GPIB interface module allows the computer to control and supply data to the printer, the plotter and the turntable driver unit.
- iii) The Parallel I/O port provides a mechanism for computer control of the digitizer unit and for supplying digital data to the high speed GANS memory.
- iv) The RS232 interface serves to communicate to and from the display terminal, the keyboard and the position encoder interface unit.

c) Encoder Interface Unit

The encoder interface unit responds to a request for position information via the RS232 link, by converting the 16 bit position data into a serial data stream which is then sent to the MLS Processor Unit.

3.3.3 SOFTWARE DESCRIPTION

The First Article MLS Test Facility (FAMAT) system is a 68000 based computer system to perform first article tests on MLS antennas. The tests are conducted by positioning a turn-table on which the MLS antenna is mounted, which simulates different aircraft approach angles. This beam, transmitted and swept by the antenna, is received by a commercial MLS receiver. The signal from the receiver is fed to a digitizer, which digitizes the data every 2 microseconds, and feeds the data to the computer. The software calculates the angle of approach, compares this with the angle as read from the turn-table, and then stores the error angle for later output. The signal is also analyzed to find dynamic side-lobe levels and all signal levels. This information is sent to the console, a printer and a plotter, thus producing documented performance characteristics of the antenna under test.

3.3.3.1 Data Flow Diagram

The FAMAT system consists of a number of inputs, each being processed in a different fashion, giving rise to a number of computed outputs. The data flow through the system is illustrated in Figure 3.2, which details all external inputs to the FAMAT, the flow of this through various processing modules, and finally all outputs to the external world.

The data flow diagram is used to divide the system into a number of modules, each of which is as independent of the others as possible, and also performs unique tasks. An attempt has been made to keep modules fully cohesive, that is, all tasks performed by a module are intimately connected. The structural breakdown of the software is illustrated in Figure 3.3, which is an SADT (Structural Analysis and Decomposition Technique) diagram for the FAMAT software. This diagram shows the potentially independent tasks within the software system. Each task is further broken down into modules. These are discussed in subsequent sections, along with detailed structure charts.

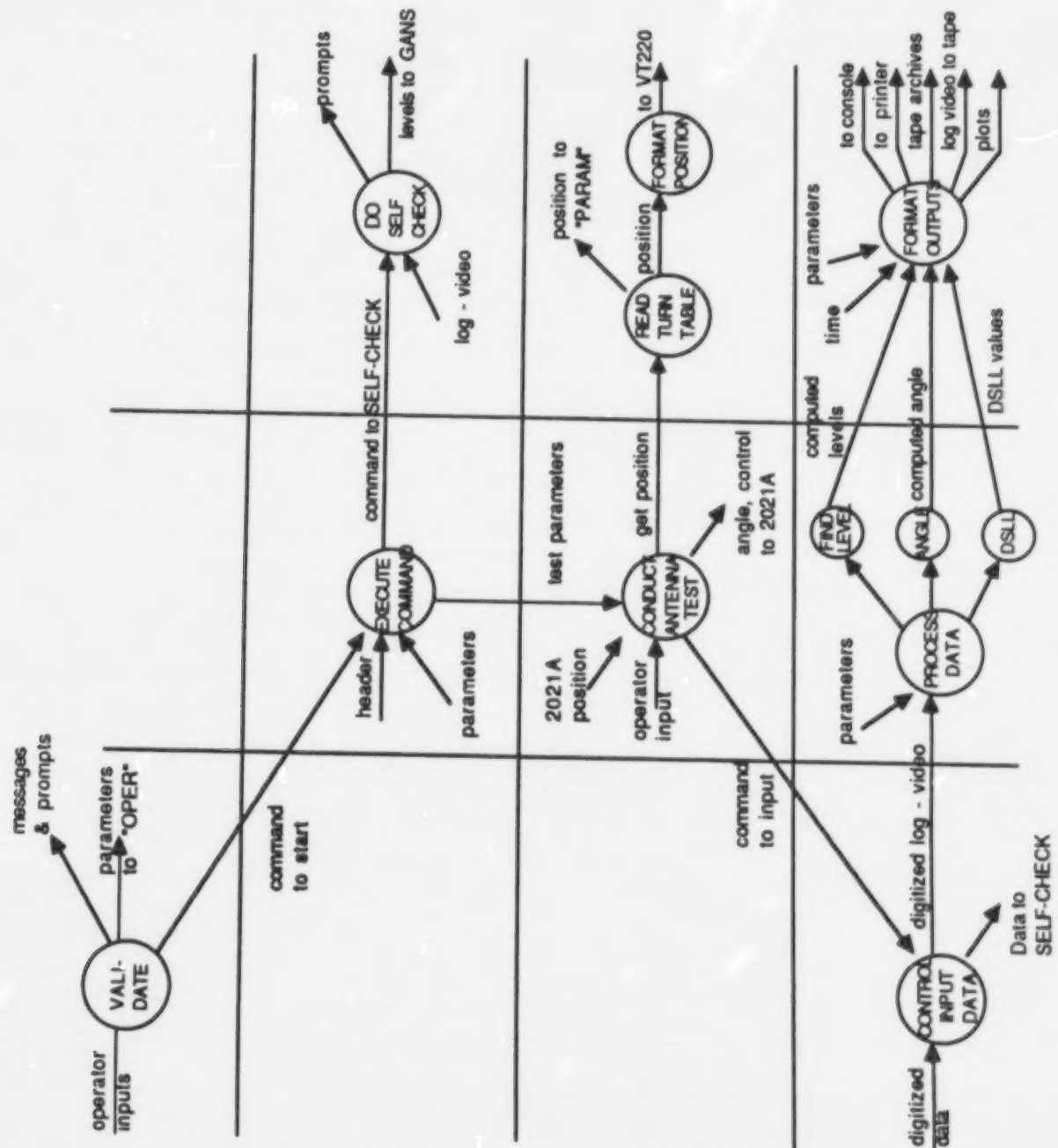


Figure 3.2 Data Flow Diagram for FAHAT

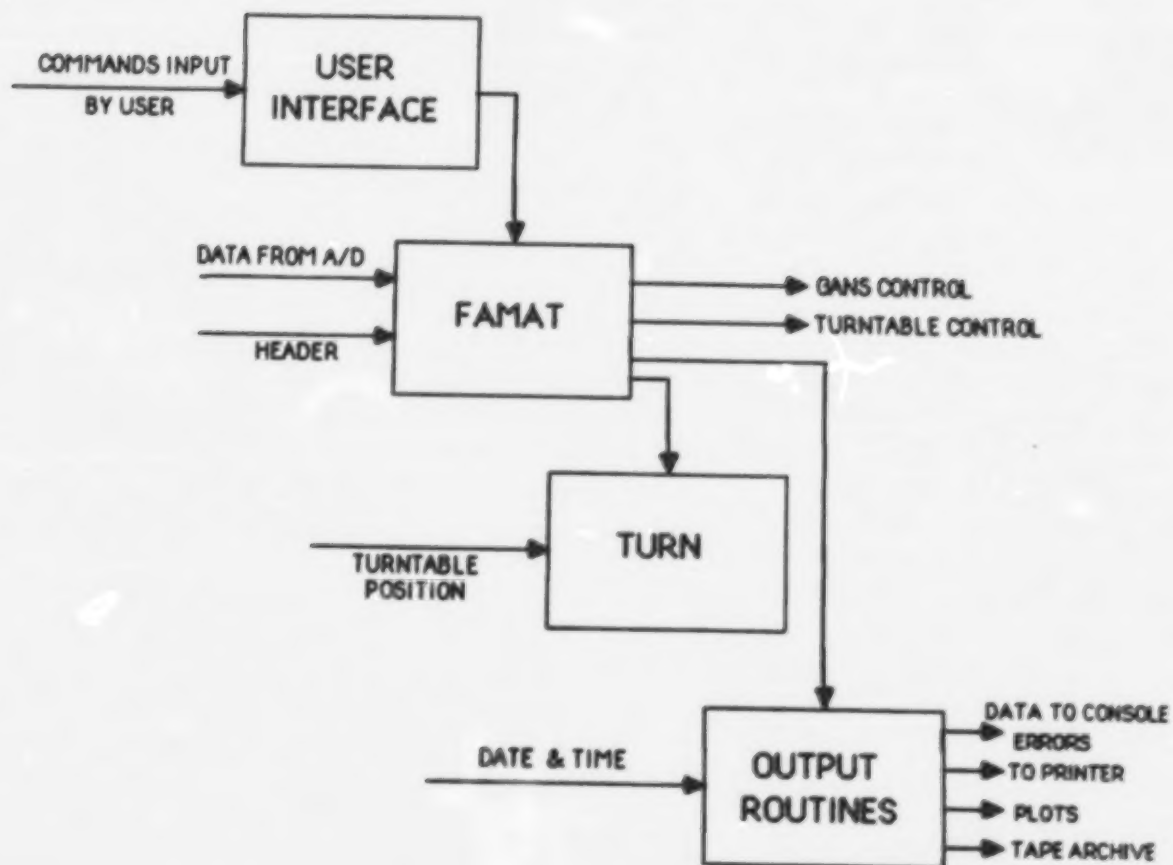


Figure 3.3 SADT Diagram for FAMAT Software

From the SADT diagram, there would appear to be four tasks in the system, however, the output functions are both embedded in FAMAT as a modules. The identification of independent tasks is based on the need for concurrency. There is only one task that really needs to be done while some other task is running; that is to read the encoder value while collecting data through the digitizer. Thus there are two concurrent tasks - one to read the encoder, and one to test the antenna.

The FAMAT software consist of two tasks:

- FAMAT - to handle signal acquisition and processing
- TURN - to handle inputs of turn-table position

The tasks are described in a later sections. The data structures and synchronization mechanisms in the system are described below.

3.3.3.2 Data Structure

The data structures used are arrays or records in PASCAL. The data used in the FAMAT system is described in Tables 3.1, 3.2, and 3.3.

Table 3.1 Structure of Record "Query"

QUERY = array [1.. 26] of records

record

PMENU	:	int	*	pointer to menu
PROMPT	:	array [1..30] of CHAR	*	prompt
MINVAL	:	REAL		
MAXVAL	:	REAL		
DEFVAL	:	REAL		
DEST	:	int	*	pointer to destination in "OPER"
PREVQ	:	int	*	pointer to prev. question
NEXT	:	array [1..5] int	*	pointers to next questions conditional on answer

end

Table 3.2 Structure of Record "PARAM"

PARAM is a record of REAL

PARAM =	
record	
BLANK	* Spare
COMMAND :	* Command to FAMAT
NEX :	* Next Operation
ANTENNA :	* Antenna under test
ELEVATION:	* Elevation of turntable
PCO :	* Phase centre offset
POLAR :	* Polarization
COVER :	* Prop. coverage
START_AZ :	* Start azimuth
STOP_AZ :	* Stop azimuth
NUMB_AZ :	* number of azimuths
NUMB_SCAN:	* # of scans
REF_ZERO :	* Reference zero position
CONTROL :	* Antenna control
C_PULSE :	* Clearance pulses
C_ANGLE :	* Clearance angle
TAPE :	* Log on tape?
HARD_COPY:	* Print?
VIDEO :	* # of log_video images
P_ERROR :	* Plot errors?
P_DSLL :	* Plot DSLL?
G_TRIG :	* GANS trigger
G_SOURCE :	* GANS Source - Int/tape/disk
G_FUNC :	* GANS function - AZ/EL/BAZ
G_DSLL :	* GANS DSLL required
O_AZIM :	* Turntable Azimuth (output)
O_ANGLE :	* Calculated angle
O_DPSK :	* Obs. DPSK level
O_OCIR :	* Obs. OCI (Right) level
O_OCIL :	* Obs. OCI (Left) level
O_CLR :	* Obs. right clearance level
O_CLL :	* Obs. left clearance level
O_TO :	* Obs. TO level
O_FRO :	* Obs. FRO level
O_DSLL_TR:	* Obs. DSLL. (TO right)
O_DSLL_TL:	* Obs. DSLL. (TO left)
O_DSLL_FR:	* Obs. DSLL. (FRO right)
O_DSLL_FL:	* Obs. DSLL. (FRO left)
O_ANGERR :	* Angular error
O_STDDEV :	* Standard deviation
O_SYM :	* Assymetry

This is equivalent to an array of REALs named OPER, for operational parameters.

OPER = array[1..26] of REALs.

Table 3.3 DATA IN "MENU"

"You may select one of the following

- 1 Antenna test
- 2 Self check
- 3 Compensate A/D
- 4 Controls
- 5 EXIT

"For the FAMAT, you may

- 1 Change antenna configuration
- 2 Change test parameters
- 3 Change outputs
- 4 EXIT

"You may select one of the following

- 1 Start FAMAT
- 2 Stop FAMAT
- 3 Start GANS
- 4 Stop GANS
- 5 EXIT

Table 3.4 Data in Record "Query"

5 Select one of the above	1.0	5.0	1.0	2	1	2	2	1	1	3	0
6 Select one of the above	1.0	4.0	1.0	0	1	4	4	17	22	1	1
7 Select one of the above	1.0	5.0	5.0	1	1	1	1	1	1	1	1
4 Antenna(0-AZ,1-EL,2-BAZ,3-HAZ)	0.0	3.0	0.0	3	2	5	5	5	5	5	5
0 Elevation offset in degrees ?	-4.0	4.0	2.0	4	4	6	6	6	6	6	6
0 Phase centre offset cm (L-R) ?	-100.0	100.0	0.0	5	5	7	7	7	7	7	7
0 Phase centre offset cm (B-F) ?	-100.0	100.0	0.0	6	6	8	8	8	8	8	8
0 Phase centre offset m (U-D) ?	-5.0	5.0	0.0	7	7	9	9	9	9	9	9
0 Polarization	? -30.0	30.0	0.0	8	8	10	10	10	10	10	10
0 Scan Limit (left)	? -90.0	0.0	-90.0	9	9	11	11	11	11	11	11
0 Scan Limit (right)	? 0.0	90.0	90.0	10	10	12	12	12	12	12	12
0 What is 2012 ref.zero	? -180.0	180.0	0.0	11	11	13	13	13	13	13	13
0 What is encoder ref.zero	? -180.0	180.0	0.0	12	12	14	14	14	14	14	14
0 Are clearance pulses present ?	0.0	1.0	1.0	13	13	2	15	15	15	15	15
0 Left clearance angle	? -90.0	0.0	-12.5	14	14	16	16	16	16	16	16
0 Right clearance angle	? 0.0	90.0	12.5	15	15	2	2	2	2	2	2
4 Number of samples/test	? 1.0	16.0	16.0	16	2	18	18	18	18	18	18
4 Antenna (1-auto,2-man)	? 1.0	2.0	2.0	17	17	19	19	19	2	19	19
4 Number of azimuths	? 1.0	2000.0	1.0	18	18	20	20	20	20	20	20
0 Start azimuth for test	? -90.0	90.0	-10.0	19	19	21	21	21	21	21	21
0 Stop azimuth for test	? -90.0	90.0	10.0	20	20	2	2	2	2	2	2
4 Archive on tape (N=0 or Y=1) ?	0.0	1.0	0.0	21	2	23	23	23	23	23	23
4 Print results (N=0 or Y=1) ?	0.0	1.0	0.0	22	22	24	24	24	24	24	24
4 # of log-video images	? 0.0	2000.0	0.0	23	23	25	25	25	25	25	25
4 Plot errors (N=0 or Y=1) ?	0.0	1.0	0.0	24	24	26	26	26	26	26	26
4 Plot DSSL (N=0 or Y=1) ?	0.0	1.0	0.0	25	25	2	2	2	2	2	2

3.3.3 SYNCHRONIZATION MECHANISMS

a) Semaphores

The two tasks in the FAMAT system use semaphores for synchronization and resource sharing. In Versados, semaphores can be created, tasks attached to them, and made to wait for the semaphore. The Versados semaphores may be any size, however, in FAMAT, they are used only as binary semaphores. The semaphores used are:

- "OUT" to control output to the console

This semaphore is used by both tasks to write to the console.

- "GETM"

This semaphore is used when the task FAMAT wants to tell task TURN it should get an angle (Getangle).

- "SEND"

This semaphore is signalled by task FAMAT to indicate it wants TURN to send angles (Senangle) in the mail.

- "ACCT"

This semaphore is signalled by task TURN to indicate it is ready to accept (Raccept) Getangle semaphores from FAMAT.

b) MAILBOXES

All multitasking systems provide means for various tasks to communicate with one another. These are known by various names in various systems, although a common name is a mailbox. In Versados, they are known as Asynchronous System Queues or ASQ's. The Versados system allows ASQ's to be used in a multitude of ways, which are discussed in the Versados manuals. In MLS, however, they are used only as mechanism for sending information asynchronously from one task to another.

In this system mail is sent between the tasks for 3 reasons. These are described below:

- The encoder zero reference is sent from FAMAT to TURN.
- FAMAT sends mail to turn to indicate it is ready to do antenna measurements.
- TURN sends mail to FAMAT when it passes the encoder readings.

3.3.3.4 Tasks

a) FAMAT Task

The function of the FAMAT task is mainly to acquire the signal and calculate the beam centre and sidelobe levels. The structure chart for this task is given in Figure 3.4. The modules that make up FAMAT are described in subsequent sections.

Module #1.0

INPUTS: --

OUTPUTS: --

PROCESS:

This is the main Program, which is responsible for initialization and Program flow. When GO.cf is executed, control is passed to FAMAT, where initialization is performed. The following are functions of the initialization section:

- create a mailbox for this task
- setup and attach the four semaphores required for the task "TURN". The semaphores used are:
 - GETM - used when the task FAMAT wants to tell task TURN it should get an angle (Getangle).
 - OUT - this semaphore is used by both tasks to indicate when it requires to write to the console. This is so the two tasks can share the device
 - SEND - signaled by task FAMAT to indicate it wants TURN to send the angles (Sendangle) in the mail
 - ACCT - signaled by task TURN to indicate it is ready to accept (Raccept) Getangle semaphores from FAMAT
- parallel port bits are initialized to 0
- the error messages sent to the console are initialized
- COMP is called to initialize the lookup table RAM on the Digitizer CCA

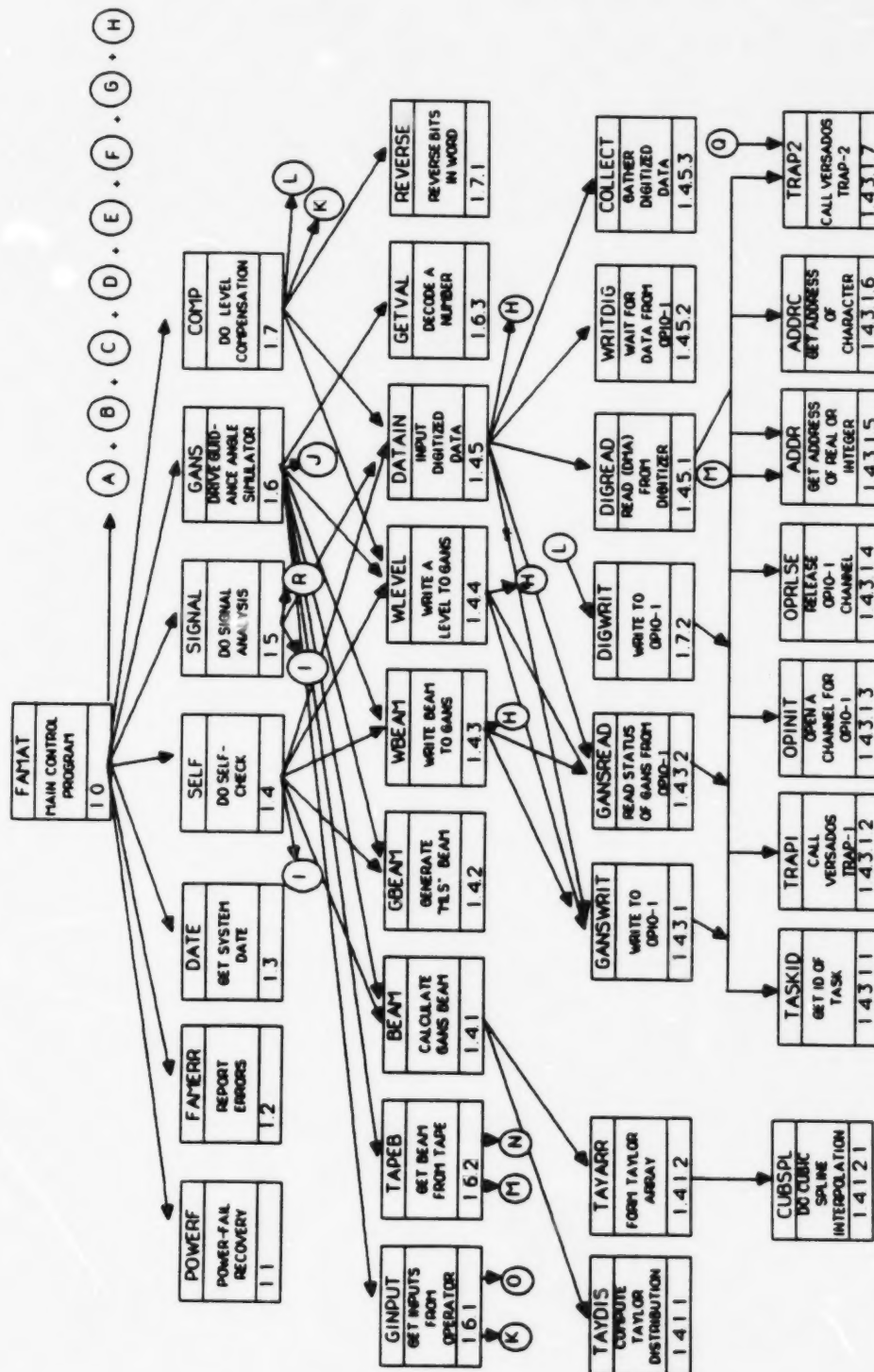
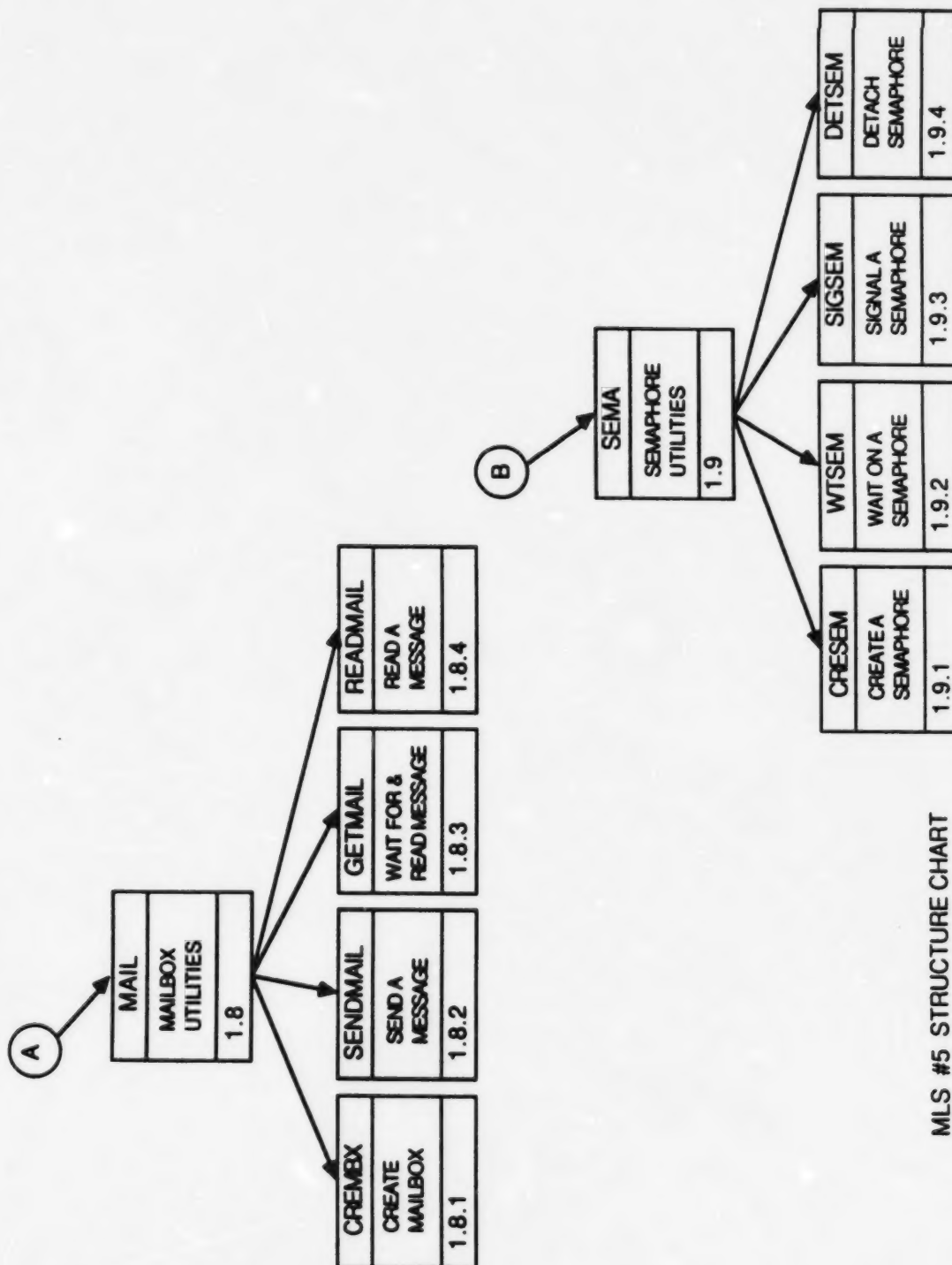


Figure 3.4 Structure Chart of FANTAT



MLS #5 STRUCTURE CHART

Figure 3.4 Structure Chart of FANAT (cont'd)

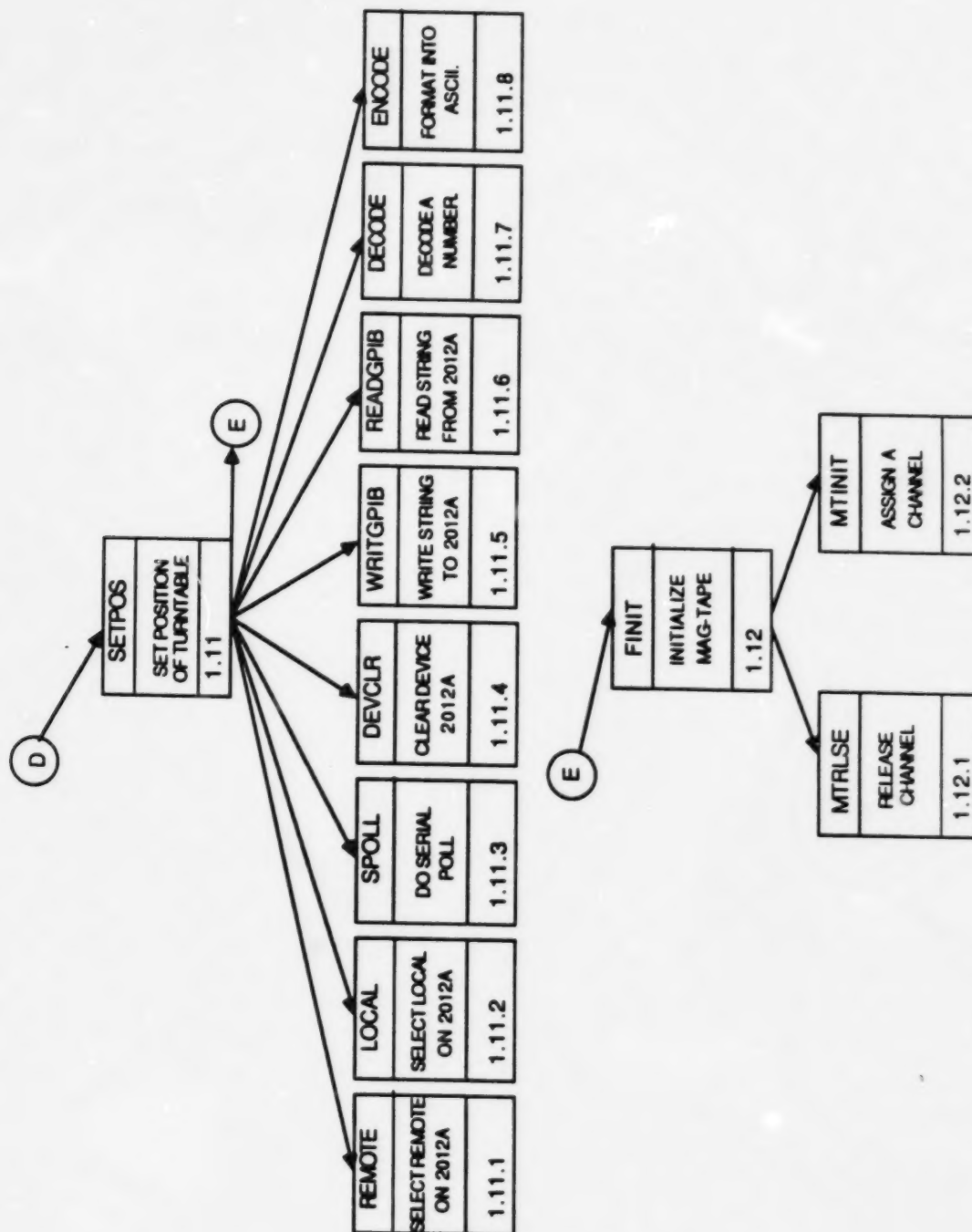


Figure 3.4 Structure Chart of FAMAT (cont'd)

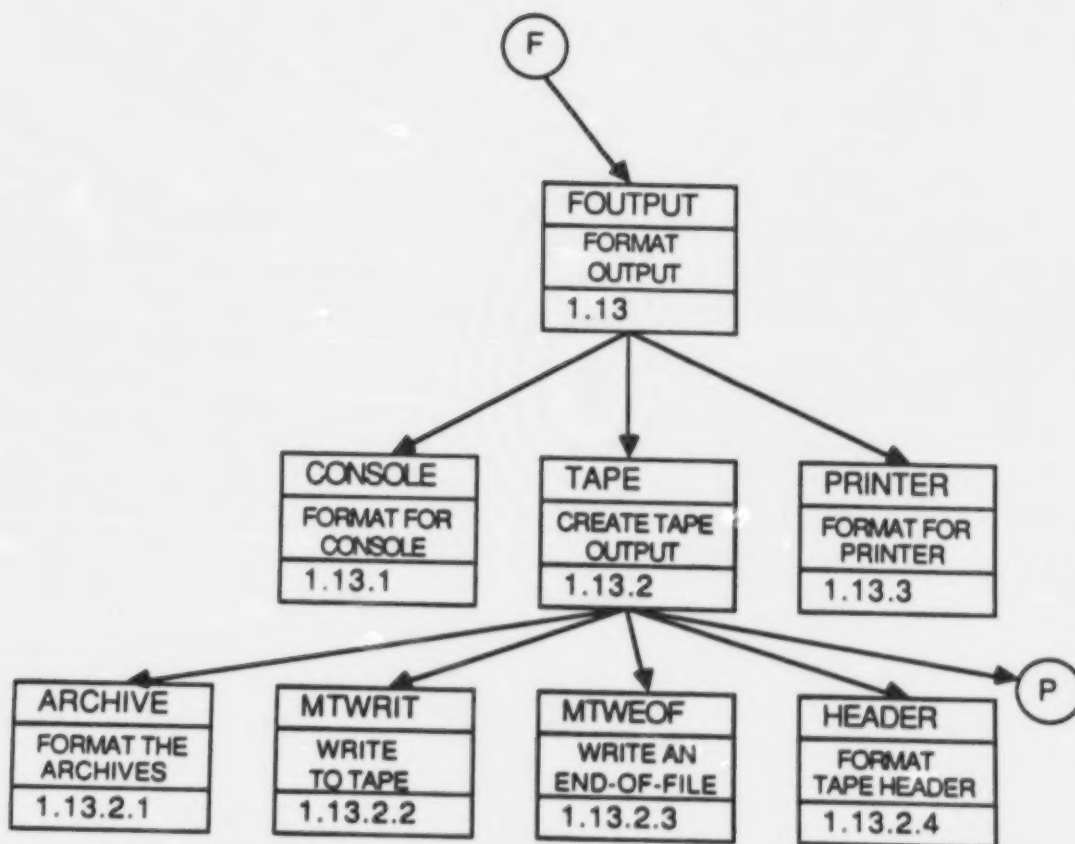


Figure 3.4 Structure Chart of FAMAT (cont'd)

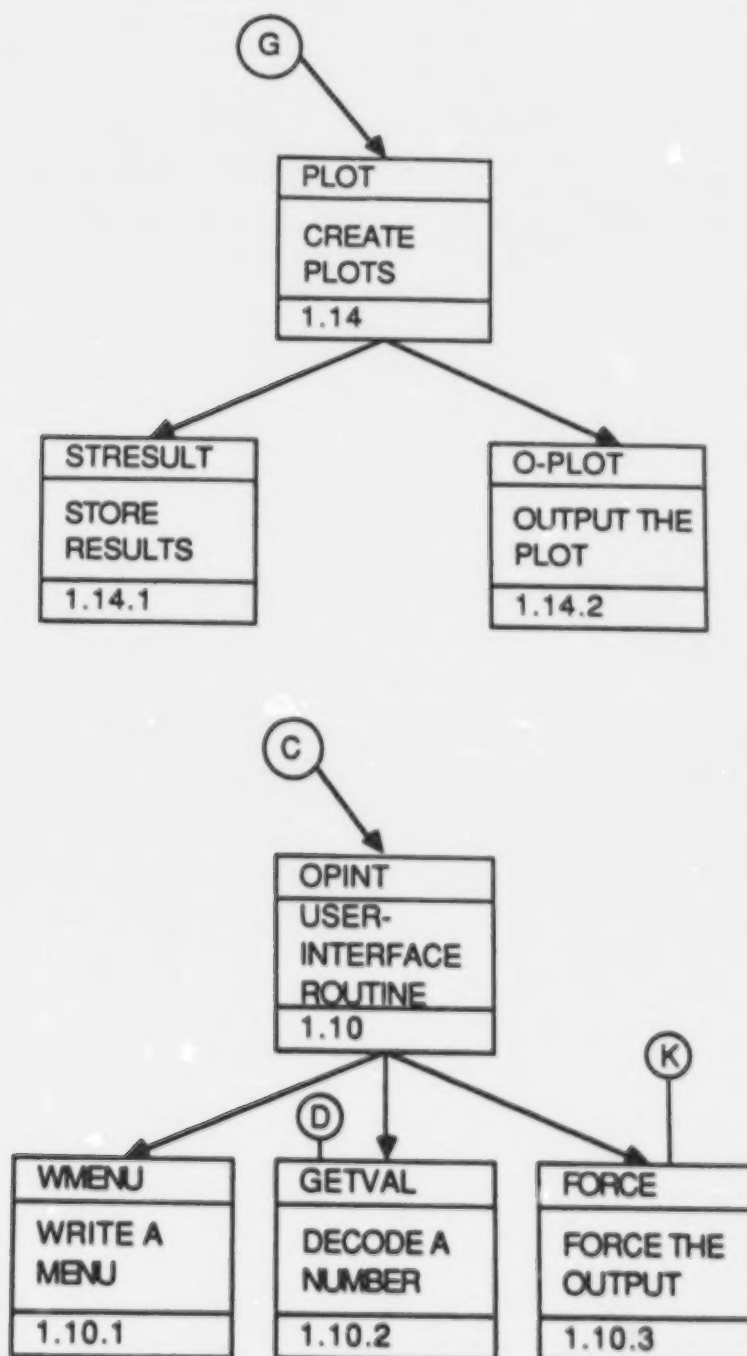


Figure 3.4 Structure Chart of FAMAT (cont'd)

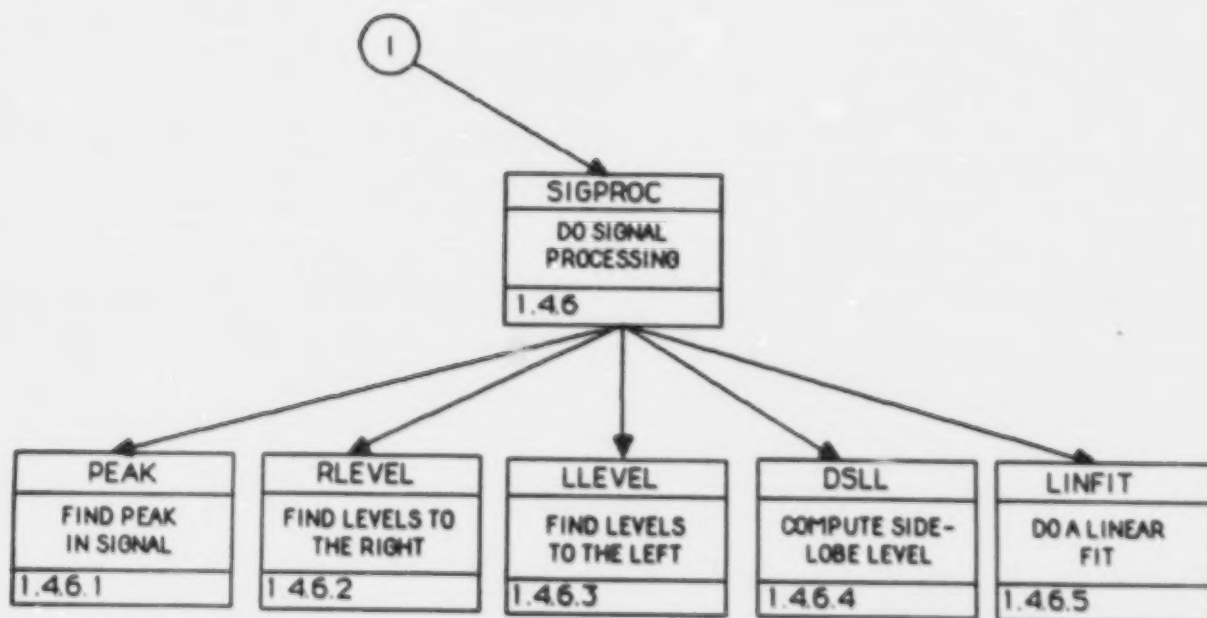


Figure 3.4 Structure Chart of FAMAT (cont'd)

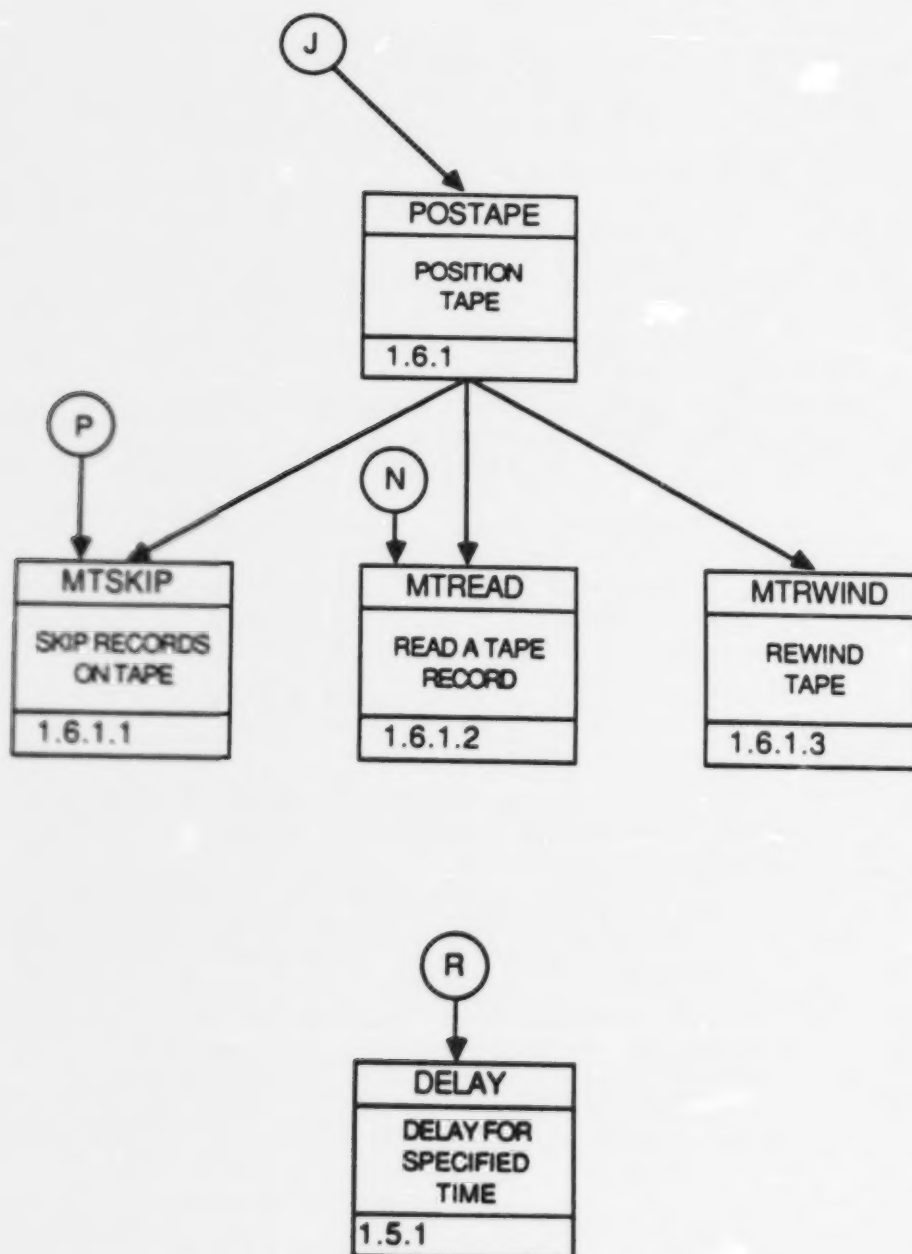


Figure 3.4 Structure Chart of FAMAT (cont'd)

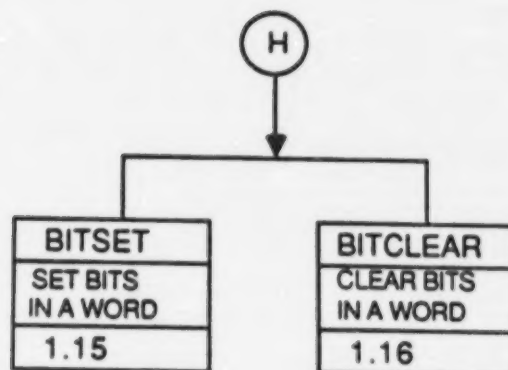


Figure 3.4 Structure Chart of FAMAT (cont'd)

Once initialization is complete, the main loop is entered until the program is exited by OPINT. POWERF is called to see if a power failure has occurred. If a power failure has occurred and the user wishes to continue in an experiment from where he/she left off, program control goes to Antenna Test. Otherwise, OPINT is called. Returning from OPINT, the tape is initialized if the user indicated tape storage required and the control goes to: Antenna Test, Self Test, Start Gans, Stop Gans or Exit (stop program) as selected by the user.

If "Antenna Test" was selected, a test description is requested which is immediately stored in data files required for plots. The function identification trigger word is sent to the digitizer board for the antenna selected. Using the Stop azimuth for test, start azimuth for test and number of azimuths, the azimuth positions where tests must be performed are calculated. If one azimuth is chosen, the start azimuth is used, the start and stop azimuths are used if two azimuths are chosen. If more than two azimuths are chosen, the start and stop azimuths as well as equally spaced positions in between are used. The azimuth positions for the stored log video pictures are calculated using the same principal.

SETPOS is then called to set the turntable to the required position. SIGNAL is called to input the data and process it. FOUTPUT is then called to output to the various output devices as selected by the user. The file "Status.ml" is updated for power failure precautions.

Once all the azimuth positions are completed, PLOT is called if the user selected plot outputs.

If "Self test" is selected, the function identification trigger is set for an azimuth antenna.

If "Start Gans" is selected, GANS is called.

If "Stop Gans" is selected, the rep. rate select bits on the GANS CCA are set to zero, selecting a rep. rate of zero.

If "Exit" is selected, the program terminates.

3.3.3.5 Command Files

a) GO.cf

GO.cf is the command file used to start program execution.

The file GO.cf assigns channels 10, 11 and 12 to the devices tape drive, 2012 positioner and the RS232 part for encoder readings respectively. Each device is set for public write, public read. The task TURN is then started running in the background. The task FAMAT is started running in the foreground with inputs and outputs (i and o) both set for the monitor, and the input parameter file is Query.ml. When task FAMAT is exited by the appropriate methods, TURN is also terminated and the 3 channels (previously opened) are closed.

b) GO2.cf

GO2.cf must be run if Famat was terminated incorrectly (i.e. if the BREAK key was pressed). If there is an assignment error when GO.cf is run, GO2.cf must be run. GO2.cf performs the same functions as GO.cf but in addition it closes each channel before assigning it.

c) FAMAT.CF

Famat.cf is called to link all modules in the task FAMAT.

d) TURN.CF

Turn.cf is called to link all modules in the task TURN.

e) COMPILE.CF

Compile.cf is the command file called to compile a modules.

4.0 PRELIMINARY TEST RESULTS

Preliminary testing of the MLS Test Facility was divided into three sets of tests, i.e.:

- Factory Acceptance Tests
- Field Demonstration
- DFL Tests

4.1 FACTORY ACCEPTANCE TESTS

The following acceptance tests were performed on the system.

a) Power Output Tests

Three different tests were performed. The CW power output of the GANS was measured, the receiver/processor gain was measured, and the processor power measurement capability was tested.

Due to the temperature sensitivity of the receiver, the receiver saturated at low temperatures (i.e.: $+10^{\circ}\text{C}$) and the processor was not able to measure high level signals within the ± 1 dB required accuracy. All other test results were within the specified limits.

b) Symmetry Test

The receiver risetime minus falltime difference was measured and found to be within specification.

c) Angle Accuracy Test

The capability of the system to measure guidance angle accurately was proven. At temperature extremes and at angle extremes, the unit failed to meet the $\pm 0.004^{\circ}$ angular accuracy objective.

d) Tape Recorder, Printer, Plotter Tests

The capability of the Analyzer to output data to the printer, plotter and digital tape recorder was proven. The ability to "read" digital tapes demonstrated.

e) Operator Interface

The operator interface was tested for several typical input errors to determine if false data could be input. These tests passed.

4.2 FIELD DEMONSTRATION

A field demonstration was arranged at DFL with a Transport Canada supplied Hazeltine MLS system. The capability of the Signal Analyzer to provide the following was demonstrated:

- i) Turntable Control
- ii) Encoder "Positioner" "Read"
- iii) Ability to measure radiated signals

Figures 4.1 and 4.2 illustrate typical outputs from the plotter, one showing angle error as function of encoder angle, the second showing Dynamic Side Lobes Level as function of encoder angle.

Figures 4.3 illustrates a typical printer output result sheet.

The capability of the system to compensate for MLS phase centre offset was also demonstrated.

Figure 4.4 illustrates the test system in its final configuration.

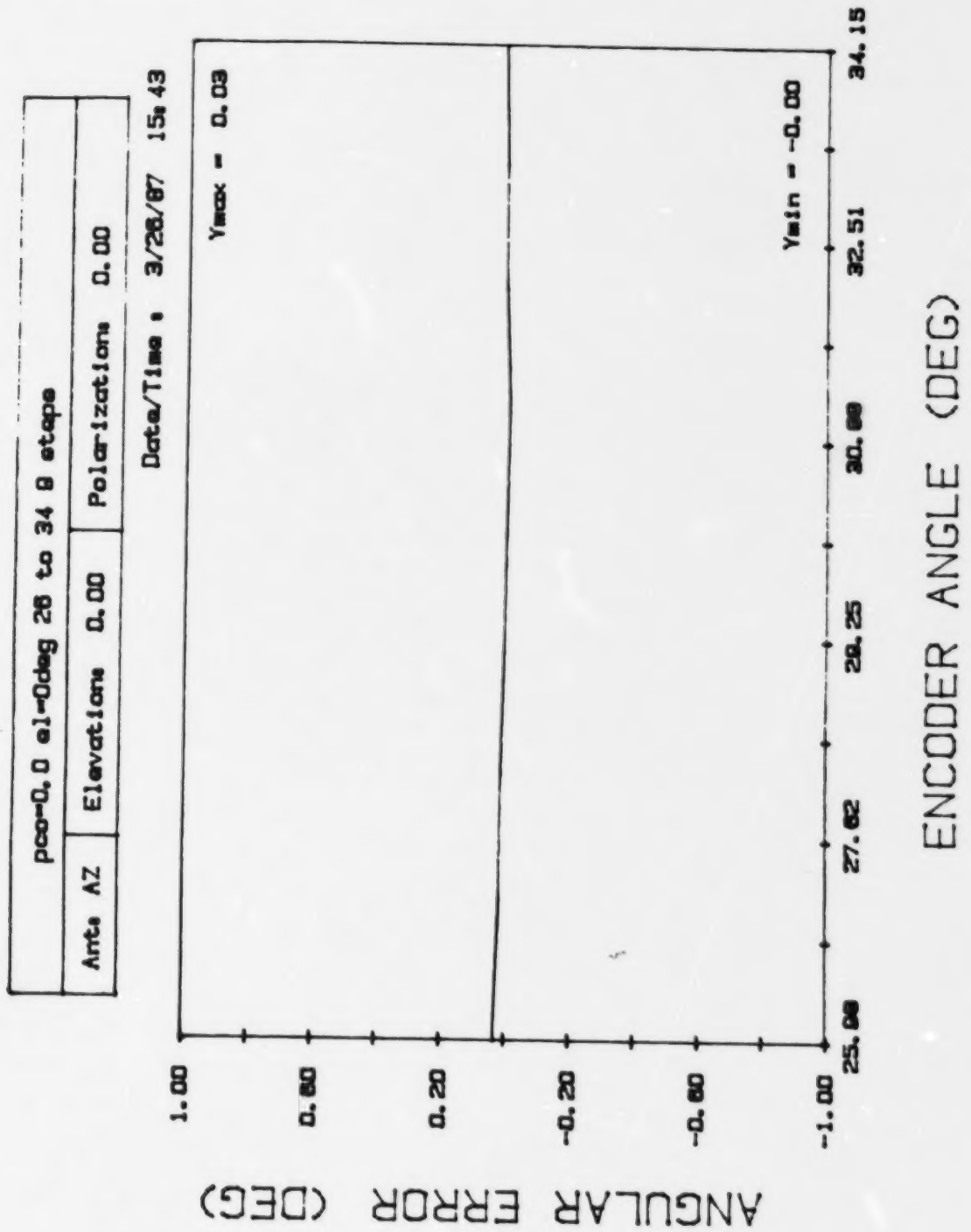


Figure 4.1 Plot of Angle Error vs. Encoder Position

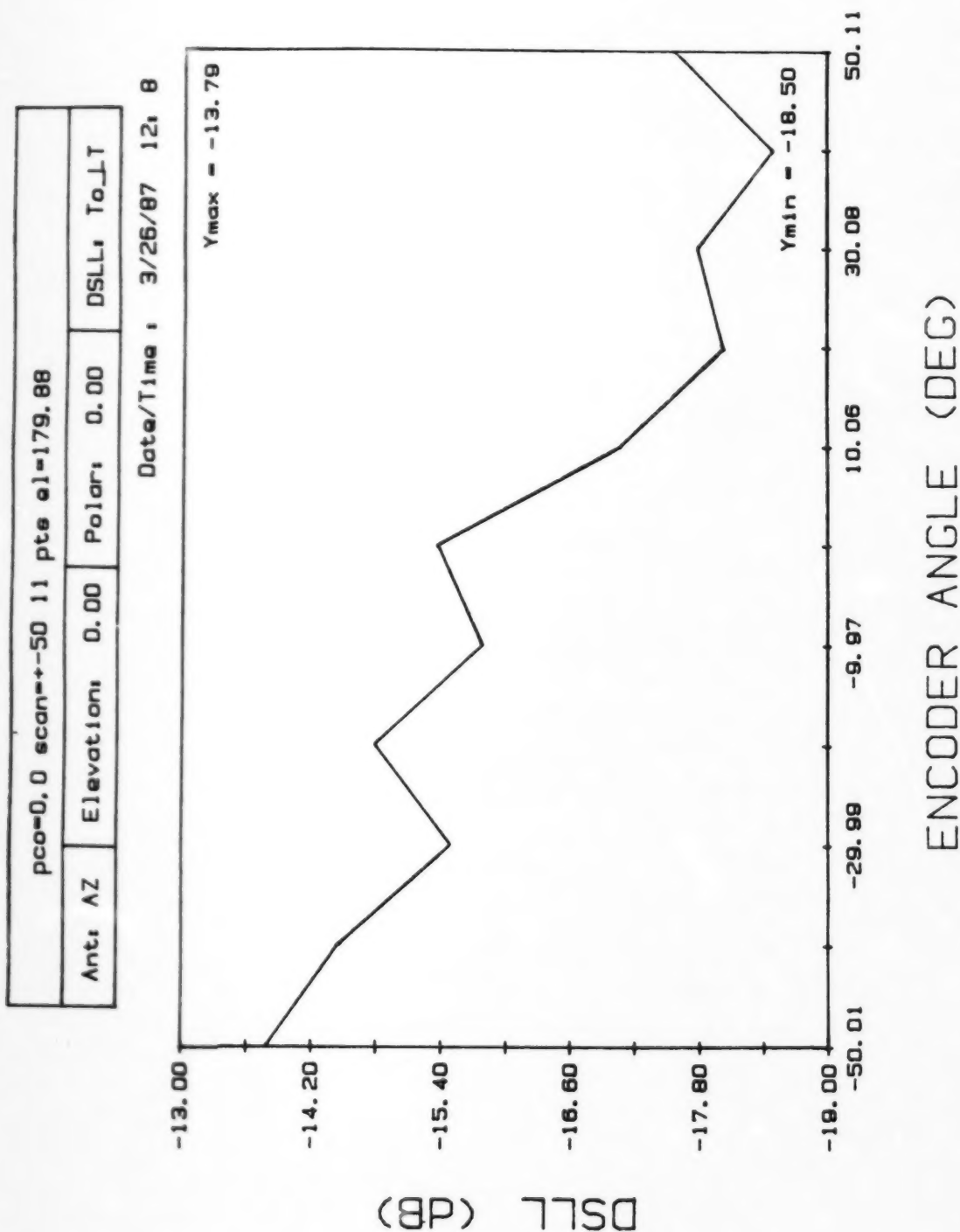


Figure 4.2 Plot of DSSL vs. Encoder Position

MLS TEST

TEST DESCRIPTION

pco=-8.89,-75.565,scan +-50,el=179.88,dsll limits =55,rcv 31.6deg
26/ 3/1987 12:48 2012A 0 = 55.69 ENCODER 0/-158.65

ANGLE ERROR	=	-0.004	deg
CALCULATED ANGLE	=	-19.909	deg
STD. DEVIATION	=	0.006	
# OF SAMPLES	=	16.000	
DPSK LEVEL	=	-20.307	dB
LT. OCI LEVEL	=	-53.238	dB
RT. OCI LEVEL	=	-53.184	dB
REAR OCI LEVEL	=	-53.270	dB
LT. CLEARANCE LEVEL	=	-54.000	dB
RT. CLEARANCE LEVEL	=	-54.000	dB
TO-BEAM LEVEL	=	-10.509	dB
FRO-BEAM LEVEL	=	-10.768	dB
DSLL TO-BEAM LT.	=	-14.721	dB
DSLL TO-BEAM RT.	=	-15.409	dB
DSLL FRO-BEAM LT.	=	-15.539	dB
DSLL FRO-BEAM RT.	=	-15.423	dB
ASYMMETRY	=	-6.303	microsec

Figure 4.3 Printer Output Form

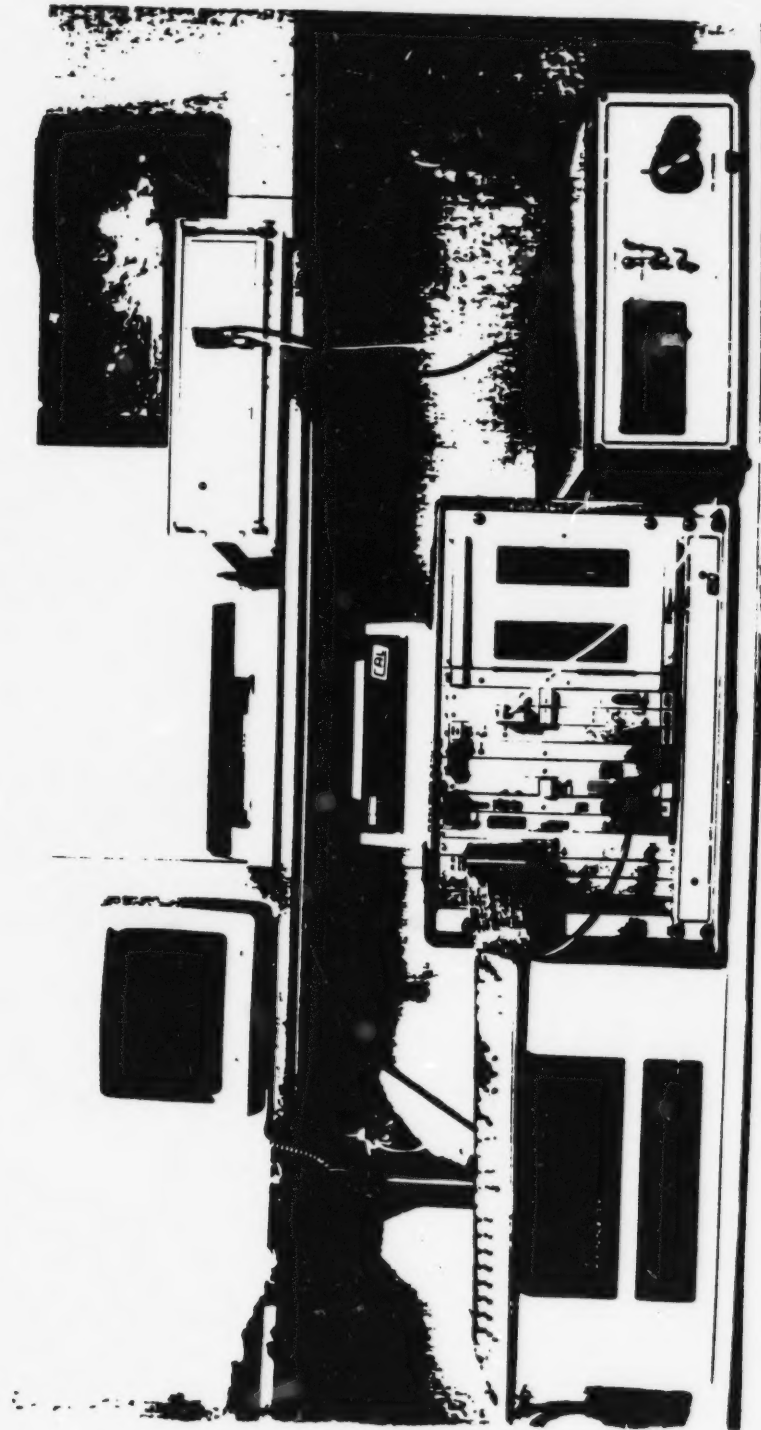


Figure 4.4 Photograph of Test System

4.3 DFL TESTS

The following tests were performed by David Florida Labs (DFL). The detailed procedure was defined by DFL staff; the procedures defined below are general guidelines. The test results were provided to CAL for review prior to dismantling the test setup.

a) ANTENNA GAIN, PATTERN, AND BEAM CENTRE

Before mounting, the Andrew antenna will be RF tested for principal plane patterns with vertical and horizontal polarization, gain, phase center at intervals of 30 degrees in spin and shimmed so that the beam is boresighted (beam peak aligned with the spin axis).

In determining phase center position, movement of the antenna to place the phase center over the center of rotation is not required. Graphic plots of phase change vs angle of rotation are required at 5.1 GHz with polarization increments of 30 degrees from 0 to 360 degrees (12 measurements). The measurements will be made with the antenna mounted on the same spin-elevation-azimuth pedestal which will be used when the antenna is mounted on the CTS tower. The antenna must be boresighted so that the beam is centered on the receive site for any orientation of its spin axis.

b) FIELD PROBING

DFL is required to check out the RF field at the DFL roof site (using the new probe arm) with a linearly polarized probe antenna with a pattern at least as broad as a C-band gain standard horn. The RF field requires probing only at the Orbit pedestal's current location (which will be used when testing Transport Canada's MLS antenna systems). The field should be probed using both vertical and horizontal polarizations at 5.06 GHz over the full travel of the probe arm and at four or more different angular positions of the probe arm (0, 45, 135, 180 degrees). The test is to be repeated for both polarizations, with the probe arm positions at 0 and 90 degrees but with the transmit antenna on the CTS tower rotated 180 degrees, to verify the accuracy of the transmit antenna boresighting. The area probed must include the entire area which will be occupied by the MLS antennas under test. (The probe antenna may be off-set from its normal mounting position on the probe arm if necessary to accomplish this.) The transmit antenna to be used for the tests will be the MLS "receiving" antenna which should be located in its permanent position on the CTS tower.

c) ENCODER ANGULAR ACCURACY VERIFICATION TEST

The angular accuracy of the azimuth digital encoder should be checked at a minimum of 36 points, distributed over 360 degrees in azimuth. The theodolite is required to be set up so that the center of its rotation is coincident with the center of rotation of the azimuth turntable. A suitable nearby target (say 10-20 ft. away) may be used to set up the centering and to perform the tests.

After the theodolite has been centered on the azimuth turntable, a series of measurements are required at 36 points in azimuth spaced approximately 10 degrees apart using the target as a reference. At each of these 36 points, ten or more readings should be taken at points separated in angle by approximately the minimum angular movement of the azimuth turntable. The azimuth angles of these points as read on the theodolite should be recorded together with the angle read from the encoder. The encoder angular resolution is about 0.0055 degrees. The difference between readings on the encoder and theodolite at the same angle should not differ by more than 0.0055 degrees. The average difference for all of the readings should be less than ± 0.011 degrees.

Should the average error exceed $\pm 0.015^\circ$, then it will be necessary to measure the actual angle at a much larger number of points and produce a detailed plot of the actual angle against the measured angle. (i.e. theodolite angle vs encoder angle).

d) MEASUREMENT OF TOWER AND BUILDING MOTION

A target with markings which permit resolution at least as fine as one quarter of an inch should be fastened to some firm structural member of the tower near the location proposed for the MLS receive antenna. This will allow monitoring of tower and building motion during periods of high wind when the rotation or sway might exceed acceptable limits.

A telescope equipped with cross hairs to be mounted on a stable mount firmly attached to the Orbit pedestal on the roof of Bldg. 65. This scope will be able to monitor the combined movement of the platform upon which the Orbit pedestal is mounted and sway of the CTS tower by monitoring the apparent movement of a target mounted on the CTS tower. An instrument with a minimum magnification of 60 appears to be required. (Sway and angular twist of the steel platform upon which the Orbit pedestal is mounted will not be measured by the encoder and, together with CTS tower sway, will cause errors in measured values of MLS scanning angles.)

5.0 CONCLUSIONS AND RECOMMENDATIONS

The results of preliminary tests have shown that the MLS antenna test system can be used to test an MLS at a properly instrumented antenna test facility for:

- i) Radiated power levels of all signals
- ii) Actual offset angle
- iii) Dynamic sidelobe level

The measurement accuracy of the test system for each of these parameters was proven in factory tests. In addition, the capability of the test system to remotely control a turntable and read the position via a remote encoder was demonstrated in a field test.

It is recommended that more exhaustive field tests be performed on the FAMAT test system using a typical MLS transmitter, thereby confirming that the FAMAT works well under all conditions. For example, tests under conditions of heavy rain and high winds should be conducted. The MLS Elevation unit should also be installed and the effect, if any, of testing an antenna "tipped" on its side be determined.

It is also recommended that the Test System be moved to an airport and used, with a probe antenna mounted on a short mast, to determine whether airport ground multipath will affect the measurement accuracy. Assuming this test is successful, it is recommended that full development of an airport Commissioning Test Facility be undertaken.

5.1 PRODUCT ENHANCEMENTS

As a result of factory tests and field tests conducted to date, a list of possible product enhancements has been generated. Although some of these features were originally included in the phase 1 system design, due to financial limitations could not be implemented.

These product enhancements are listed below:

- a) Elevation position of turntable to be read by computer rather than manually input be operator.
- b) Increase memory to 4 Mbytes to permit 32 scans to be stored.
- c) Add 10 dB beamwidth test and multipath test.
- d) Design and implement a test procedure to prove GANS absolute angle accuracy.
- e) Increase AZ scan limits to $\pm 180^\circ$.
- f) Replace Bendix MLS 20A receiver with a temperature stable, low noise downconverter/detector. (This is desirable to reduce temperature limitations and noise limitations on performance).
- g) If required, implement a receiver non-linearity compensation mode.

As the user becomes more familiar with use of the equipment, other features may become obvious as being highly desirable. It is recommended that a list of these desirable features be prepared, and the most cost effective of these modifications be added to the system.

